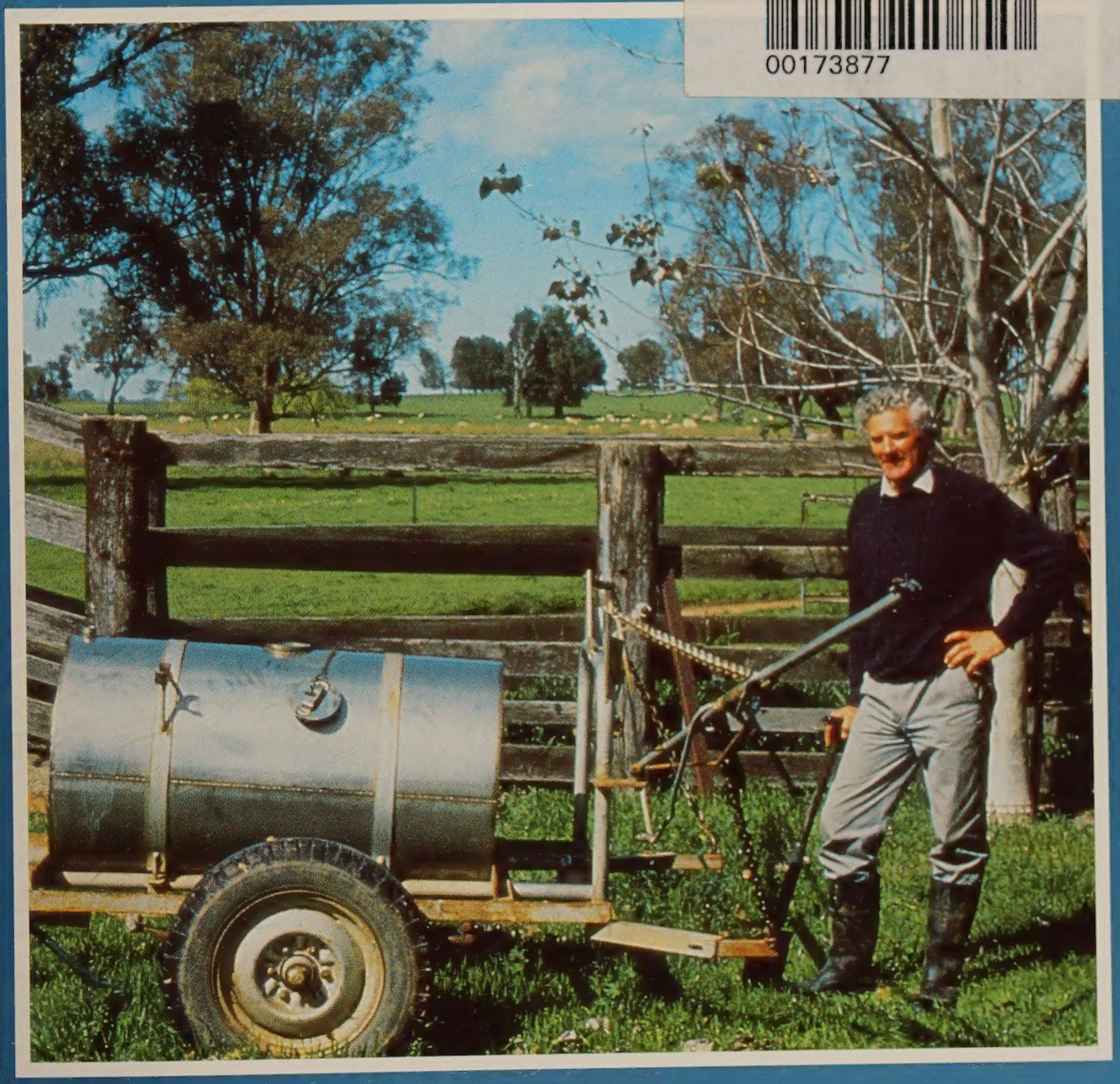
AMERICAN JOURNAL OF ALTERNATIVE AGRICULTURE

CAB INTERNATIONAL
00173877



Winter, 1995 *Volume 10, Number 1*

Alternative Agriculture News

A monthly newsletter available from Henry A. Wallace Institute for Alternative Agriculture

Noted for its succinct yet comprehensive coverage, **Alternative Agriculture News** reports on action by all alternative agriculture groups. It covers:

- Universities and government agencies.
- Non-profit organizations.
- Industry.
- Environmental and farm groups.
- Consumer organizations.
- Private/public sector cooperative efforts.

By reading **Alternative Agriculture News**, you will be well informaed about all of the major developments and trends in alternative agriculture.

HERE'S HOW TO SUBSCRIBE:

Rates for INDIVIDUAL Subscribers:

Alternative Agriculture News:
(12 issues)

$16 - U.S.
$21 - Canada & Mexico
$22 - Other Countries

American Journal of Alternative Agriculture:
(4 issues)

$24 - U.S.
$27 - Canada & Mexico
$28 - Other Countries

Combination Subscription:
Journal & Newsletter

$35 - U.S.
$43 - Canada & Mexico
$45 - Other Countries

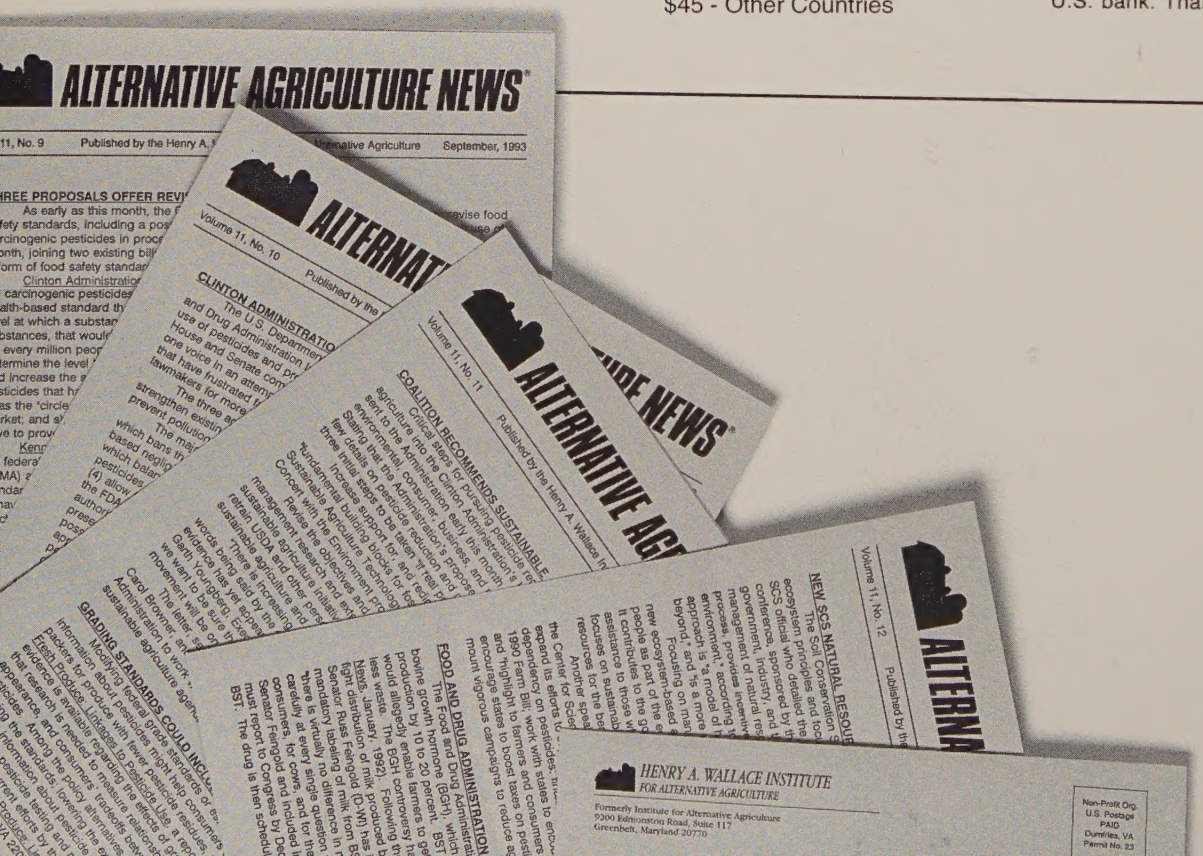
NOTE: ½ price for students with copy of student I.D.

Rates for LIBRARY subscriptions:

$44 - U.S.
$52 - Canada & Mexico
$54 - Other Countries

Please send a check payable to the:
Wallace Institute
9200 Edmonston Road, Suite 117
Greenbelt, Maryland 20770-1551

Outside USA:
Please pay with postal money order or check drawn on a U.S. bank. Thank You!



AMERICAN JOURNAL OF ALTERNATIVE AGRICULTURE®

1995
Volume 10, Number 1

CAB INTERNATIONAL
Library Services Centre
- 1 APR 1995

TABLE OF CONTENTS

Forum on Alternative Agriculture Research Policy

3 **The life cycle of alternative agricultural research** • Molly D. Anderson

10 **Making alternative agriculture research policy** • Katherine Reichelderfer Smith

19 **Removing applied agricultural research from the academy** • William Lockeretz

Other Feature Articles

25 **The relative sustainability of alternative, conventional, and reduced-till farming systems** • James D. Smolik, Thomas L. Dobbs, and Diane H. Rickerl

he Henry A. Wallace Institute for Alternative Agriculture was founded in 1983 to help dispel myths and overcome misperceptions about the economic and environmental characteristics and potential of alternative farming systems. Through research, velopment, we are working with grassroots advocates, farmers, universities, and governand disseminate sound information on sustainable farming systems and technologies.

pport the Institute's efforts, please fill out the information inside and enclose your tax-
Thank you.

HENRY A. WALLACE INSTITUTE FOR ALTERNATIVE AGRICULTURE

of Rhode Island • Robert I. Papendick, USDA-ARS • James F. Parr, International Nature Farming Research Center, Bellingham, Washington • Richard L. Ridgway, USDA-ARS • Douglas L. Young, Washington State University • Raymond R. Weil, University of Maryland.

Wallace Institute Board of Directors

Dr. Anne K. Vidaver, President, Lincoln, Nebraska*Mrs. Jean Wallace Douglas, Honorary President, Washington, DC*Dr. David F. Bezdicek, Vice President, Pullman, Washington*Dr. John C. Gordon, Secretary, New Haven, Connecticut*Dr. James W. Gibbons, Treasurer, Ozark, Arkansas* Dr. Cornelia Butler Flora, Ames, Iowa*Mr. Michael Heller, Upper Marlboro, Maryland* Dr. Frederick L. Kirschenmann, Windsor, North Dakota*Dr. Frederick R. Magdoff, Burlington, Vermont*Dr. Esther Nickel, Jackson, Minnesota*Dr. Mazo Price, Pine Bluff, Arkansas*Mr. James H. Stephenson, Carlisle, Pennsylvania*Mr. Gregory C. Watson, Falmouth, Massachusetts.

Journal Staff

Editor — *Garth Youngberg*
Technical Editor — *William Lockeretz*
Associate Technical Editors —*Paul B. Marsh*
—*Neill Schaller*
—*Marion E. Simpson*
—*Katherine R. Smith*
Book Review Editors — *Thomas C. Edens*
— *James F. Parr*
Assistant to the Editor —*Sarah C. Byler*
Circulation—*Joanna L. Hildebrand*
—*Nancy L. Ward*
Art Director— *Randy White*

The *American Journal of Alternative Agriculture* (ISSN 0889-1893) is published quarterly by the Henry A. Wallace Institute for Alternative Agriculture, Inc., 9200 Edmonston Road, Suite 117, Greenbelt, Maryland 20770-1551, in collaboration with the Center for Agriculture, Food and Environ- lutrition, Tufts University, Med- tts 02155. Neither the Wallace University is responsible for inions expressed by authors.

nformation

l subscription rates: Library/ utions $44—US; $46—Canada –all other countries. Individuals anada and Mexico; $28—all tudents $12—US; $14—Canada –all other countries. Second at Greenbelt, MD. Postmaster: ges to *American Journal of lture*, 9200 Edmonston Road, elt, MD 20770-1551.

te Information

Wallace Institute for Alternative nprofit, tax-exempt research and tion established in 1983 to en- ate the adoption of cost-effective, g and environmentally-sound lt works closely with producer arch and education institutions, encies in promoting a sustain- tem.
clude providing a national informa- serving as a voice for sustain- Washington, and developing and rch and educational outreach programs. It holds an annual scientific symposium and publishes a monthly newsletter.

The Institute is governed by a grass roots Board of Directors, which includes several commercial-scale organic farmers, and maintains a small professional staff. It is supported by memberships and donations and grants from foundations, corporations, and individuals.

Cover Photo

The cover photo shows John Greenwood, Victoria, Australia, farmer standing next to his Bio-Dynamic Preparations 500 Applicator. Photo supplied by Dr. John P. Reganold, Department of Crop and Soil Sciences, Washington State University, Pullman.

Alternative Agriculture News

A monthly newsletter available from Henry A. Wallace Institute for Alternative Agriculture

Noted for its succinct yet comprehensive coverage, **Alternative Agriculture News** reports on action by all alternative agriculture groups. It covers:

- Universities and government agencies.
- Non-profit organizations.
- Industry.
- Environmental and farm groups.
- Consumer organizations.
- Private/public sector cooperative efforts.

By reading **Alternative Agriculture News**, you will be well informaed about all of the major developments and trends in alternative agriculture.

HERE'S HOW TO SUBSCRIBE:

Rates for INDIVIDUAL Subscribers:

Alternative Agriculture News:
(12 issues)

NOTE: ½ price for students with copy of student I.D.

Rates for LIBRARY subscriptions:

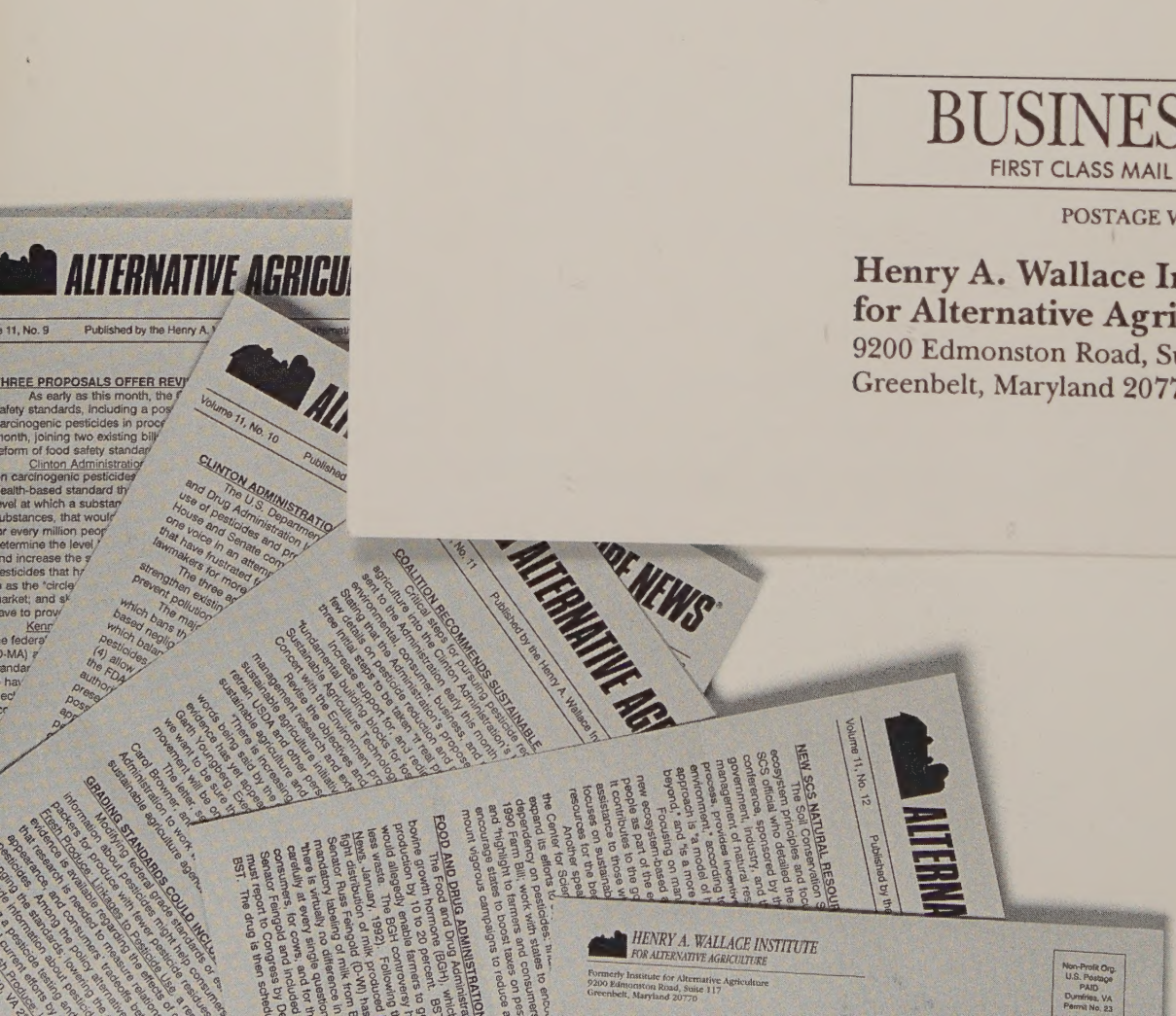
Recycled paper

BUSINESS REPLY M

FIRST CLASS MAIL PERMIT NO. 6232 GREENBELT

POSTAGE WILL BE PAID BY ADDRESSEE

Henry A. Wallace Institute
for Alternative Agriculture
9200 Edmonston Road, Suite 117
Greenbelt, Maryland 20770-9893



AMERICAN JOURNAL OF ALTERNATIVE AGRICULTURE®

1995
Volume 10, Number 1

CAB INTERNATIONAL
Library Services Centre
- 1 APR 1995

TABLE OF CONTENTS

Forum on Alternative Agriculture Research Policy

3 **The life cycle of alternative agricultural research** • Molly D. Anderson

10 **Making alternative agriculture research policy** • Katherine Reichelderfer Smith

19 **Removing applied agricultural research from the academy** • William Lockeretz

Other Feature Articles

25 **The relative sustainability of alternative, conventional, and reduced-till farming systems** • James D. Smolik, Thomas L. Dobbs, and Diane H. Rickerl

36 **Soil quality and profitability of biodynamic and conventional farming systems: A review** • John P. Reganold

Departments

Book Notices—18 • Upcoming Events—35 • Resources—45 • Book Reviews—46 • Institute News—48

Journal Editorial Board

Miguel A. Altieri, University of California at Berkeley • Molly D. Anderson, Tufts University • Lloyd A. Andres, USDA-ARS • David F. Bezdicek, Washington State University • Harold F. Breimyer, University of Missouri • Michael C. Brumm, University of Nebraska • Frederick H. Buttel, University of Wisconsin • Katherine L. Clancy, Syracuse University • Eliot Coleman, Harborside, Maine • Kenneth A. Cook, Center for Resource Economics, Washington, DC • R. James Cook, USDA-ARS • John W. Doran, USDA-ARS • Sara Ebenreck, St. Mary's College • Thomas C. Edens, Michigan State University • Frank P. Eggert, University of Maine • Lloyd F. Elliott, USDA-ARS • A. Dale Flowerday, Pioneer Hi-Bred International • Charles A. Francis, University of Nebraska • Stephen R. Gliessman, University of California at Santa Cruz • Joan Gussow, Columbia University • Don F. Hadwiger, Iowa State University • Richard R. Harwood, Michigan State University • Glenn A. Helmers, University of Nebraska • Sharon B. Hornick, International Nature Farming Research Center, Bellingham, Washington • Larry D. King, North Carolina State University • Dietrich Knorr, University of Delaware • J. Patrick Madden, Madden Associates • Robert H. Miller, University of Rhode Island • Robert I. Papendick, USDA-ARS • James F. Parr, International Nature Farming Research Center, Bellingham, Washington • Richard L. Ridgway, USDA-ARS • Douglas L. Young, Washington State University • Raymond R. Weil, University of Maryland.

Wallace Institute Board of Directors

Dr. Anne K. Vidaver, President, Lincoln, Nebraska*Mrs. Jean Wallace Douglas, Honorary President, Washington, DC*Dr. David F. Bezdicek, Vice President, Pullman, Washington*Dr. John C. Gordon, Secretary, New Haven, Connecticut*Dr. James W. Gibbons, Treasurer, Ozark, Arkansas*
Dr. Cornelia Butler Flora, Ames, Iowa*Mr. Michael Heller, Upper Marlboro, Maryland*
Dr. Frederick L. Kirschenmann, Windsor, North Dakota*Dr. Frederick R. Magdoff, Burlington, Vermont*Dr. Esther Nickel, Jackson, Minnesota*Dr. Mazo Price, Pine Bluff, Arkansas*Mr. James H. Stephenson, Carlisle, Pennsylvania*Mr. Gregory C. Watson, Falmouth, Massachusetts.

Journal Staff

Editor — *Garth Youngberg*
Technical Editor — *William Lockeretz*
Associate Technical Editors —*Paul B. Marsh*
—*Neill Schaller*
—*Marion E. Simpson*
—*Katherine R. Smith*
Book Review Editors — *Thomas C. Edens*
— *James F. Parr*
Assistant to the Editor —*Sarah C. Byler*
Circulation—*Joanna L. Hildebrand*
—*Nancy L. Ward*
Art Director— *Randy White*

The *American Journal of Alternative Agriculture* (ISSN 0889-1893) is published quarterly by the Henry A. Wallace Institute for Alternative Agriculture, Inc., 9200 Edmonston Road, Suite 117, Greenbelt, Maryland 20770-1551, in collaboration with the Center for Agriculture, Food and Environment, School of Nutrition, Tufts University, Medford, Massachusetts 02155. Neither the Wallace Institute nor Tufts University is responsible for statements and opinions expressed by authors.

Subscription Information

Annual Journal subscription rates: Library/Government/Institutions $44—US; $46—Canada and Mexico; $48—all other countries. Individuals $24—US; $26—Canada and Mexico; $28—all other countries. Students $12—US; $14—Canada and Mexico; $16—all other countries. Second Class postage paid at Greenbelt, MD. Postmaster: Send address changes to *American Journal of Alternative Agriculture*, 9200 Edmonston Road, Suite 117, Greenbelt, MD 20770-1551.

Wallace Institute Information

The Henry A. Wallace Institute for Alternative Agriculture is a nonprofit, tax-exempt research and education organization established in 1983 to encourage and facilitate the adoption of cost-effective, resource-conserving and environmentally-sound farming methods. It works closely with producer groups, public research and education institutions, and government agencies in promoting a sustainable agriculture system.

Its programs include providing a national information clearinghouse, serving as a voice for sustainable agriculture in Washington, and developing and implementing research and educational outreach programs. It holds an annual scientific symposium and publishes a monthly newsletter.

The Institute is governed by a grass roots Board of Directors, which includes several commercial-scale organic farmers, and maintains a small professional staff. It is supported by memberships and donations and grants from foundations, corporations, and individuals.

Cover Photo

The cover photo shows John Greenwood, Victoria, Australia, farmer standing next to his Bio-Dynamic Preparations 500 Applicator. Photo supplied by Dr. John P. Reganold, Department of Crop and Soil Sciences, Washington State University, Pullman.

FROM THE EDITOR

With this issue, the *American Journal of Alternative Agriculture* enters its 10th year of publication. We have diligently sought throughout to maintain the highest professional and scientific standards, and we will continue to do so. In large measure, *AJAA*'s growing visibility and credibility stem from the dedication of the professionals listed below who have so generously given of their time and energy as reviewers during the past two years. On behalf of our editorial staff, I want to acknowledge and thank them for responding so promptly and thoroughly to our requests for their help. It is reassuring to know that these reviewers and others are willing to contribute in this critically important way to the continuing development and recognition of the scientific basis of alternative agriculture.

I. Garth Youngberg, Editor

Patricia Allen, *University of California, Santa Cruz*; Molly D. Anderson, *Tufts University*; Jill Shore Auburn, *University of California, Davis*; Sandra Batie, *Michigan State University*; Jim Bender, *Weeping Water, NE*; Walt Bentley, *University of California*; Edwin Berry, *USDA-ARS*; Gabor Bethlenfalvay, *USDA-ARS*; Elizabeth Bird, *Center for Rural Affairs*; Engelhard Boehncke, *University of Kassel*; Harold Breimyer, *University of Missouri*; Michael Brumm, *University of Nebraska*; Robert L. Bugg, *University of California, Davis*; Gordon Bultena, *Iowa State University*; Bees Butler, *University of California, Davis*; Fred Buttel, *University of Wisconsin*; Denny Caneff, *Wisconsin Rural Development Center*; Gerald Carlson, *North Carolina State University*; Craig Chase, *Iowa Cooperative Extension Service*; Nancy Cohen, *University of Massachusetts*; Ken Cook, *Environmental Working Group*; R. James Cook, *USDA-ARS*; Joe Costante, *University of Vermont*; Kent Crookston, *University of Minnesota*; Richard Cruse, *Iowa State University*; James D. Dutcher, *University of Georgia*; Stan Daberkow, *USDA-ERS*; Colette DePhelps, *Washington State University*; Penelope Diebel, *Kansas State University*; James J. Dinsmore, *Iowa State University*; Jeff Dlott, *University of California, Berkeley*; Tom Dobbs, *South Dakota State University*; Otto Doering, *Purdue University*; John Doran, *University of Nebraska*; Laurie Drinkwater, *Rodale Institute Research Center*; Frank Drummond, *University of Maine*; Mike Duffy, *Iowa State University*; Joel C. Edelstein, *University of Colorado, Denver*; Keith Edmisten, *North Carolina State University*; Jim Ellis, *University of Nebraska*; Jeff Erickson, *Tufts University*; Cornelia Flora, *Iowa State University*; Jan Flora, *Iowa State University*; Charles Francis, *University of Nebraska*; Jacques Franco, *California Department of Food and Agriculture*; Julia Freedgood, *American Farmland Trust*; John Gardner, *North Dakota State University*; John Gerber, *University of Massachusetts*; Gilbert Gillespie, *Cornell University*; Peter J. Goldmark, *Okanagon, WA*; Walter Goldstein, *Michael Fields Agricultural Institute*; Eleanor Groden, *University of Maine*; Don Hadwiger, *Iowa State University*; Chuck Hassebrook, *Center for Rural Affairs*; John Havlin, *Kansas State University*; Glenn Helmers, *University of Nebraska*; Elizabeth Henderson, *Rose, NY*; David Holm, *Hampshire College*; Mark Honeyman, *Iowa State University*; John Ikerd, *University of Missouri*; Dana Jackson, *Land Stewardship Project*; Desmond Jolly, *University of California, Davis*; P.K. Nair, *University of Florida*; Doug Karlen, *USDA-ARS*; Larry King, *North Carolina State University*; Terry Klopfenstein, *University of Nebraska*; Alan Knight, *USDA-ARS*; Ron Kroese, *National Center for Appropriate Technology*; William Lacy, *Cornell University*; Paul Lasley, *Iowa State University*; Laura Lengnick, *USDA-ARS*; Matt Liebman, *University of Maine*; Mark Lindhult, *University of Massachusetts*; Sally Logsdon, *USDA-ARS*; John Luna, *Oregon State University*; Daniel Mahr, *University of Wisconsin*; Wendy Mechaber, *Tufts University*; Patricia D. Millner, *USDA-ARS*; Bill Murphy, *University of Vermont*; Patricia Norris, *Oklahoma State University*; Peter Nowak, *University of Wisconsin*; Kathleen Painter, *Washington State University*; Robert Papendick, *USDA-ARS*; Gregory Porter, *University of Maine*; Josh Posner, *University of Wisconsin*; Ed Prigge, *West Virginia University*; Daniel Putnam, *University of Minnesota*; A.C.S. Rao, *Washington State University*; John Reganold, *Washington State University*; Tom Richard, *Cornell University*; Diane Rickerl, *South Dakota State University*; Ann Robinson, *Izaak Walton League*; Beatrice Rogers, *Tufts University*; Carl Rosen, *University of Minnesota*; Andrew Rowan, *Tufts University*; Priscilla Salant, *Washington State University*; Peter Schaeffer, *South Dakota State University*; Charles Shapiro, *University of Nebraska*; Miranda Smith, *Belchertown, MA*; James Smolik, *South Dakota State University*; Steve Stevenson, *University of Wisconsin*; Scott Swinton, *Michigan State University*; C.R. Taylor, *Auburn University*; Donald Taylor, *South Dakota State University*; D.O. TeBeest, *University of Arkansas*; Steve Temple, *University of California, Davis*; Michael Thompson, *Iowa State University*; Angela Tregear, *University of Wales, Aberystwyth*; Mark Van Horn, *University of California, Santa Cruz*; Suzanne Vaupel, *Sacramento, CA*; Gerald Walter, *University of Illinois*; Matt Werner, *University of California, Santa Cruz*; Ray R. Weil, *University of Maryland*; Jennifer Wilkins, *Cornell University*; Sarah Wright, *USDA-ARS*; Roger Wrubel, *Tufts University*; Frank Young, *USDA-ARS*.

The life cycle of alternative agricultural research

Molly D. Anderson

Abstract. *The acceptance and utility of alternative agricultural research can be enhanced by better incorporating social sciences and issues and by broadening its scope to the entire food system rather than focusing only on food production. Researchers have made strong contributions in developing and evaluating alternative agricultural technologies, but research attention also is needed to articulate strategies for synthesizing those technologies into coherent strategies, to examine the social effects of different scenarios, and to create better decisionmaking processes for ensuring broad-based knowledgeable participation in the choices among alternative strategies. Research that addresses human needs beyond food and fiber will help build truly alternative and desirable agricultural systems.*

Key words: alternative agriculture, sustainable agriculture, food system, interdisciplinary research, citizen participation

Alternative agriculture is the confluence of a research area and social movement. Considering its life cycle helps to show how the present point has been reached and what may have been overlooked on this path. This paper discusses the growth of alternative agricultural research, its present emphases, and some research challenges in implementing the broad concepts that have developed in alternative agriculture.

The external impetus to change agricultural research to be more accountable to the public and less damaging to the physical environment has been truly significant (Hadwiger, 1982; Browne, 1988), although less so than many advocates had hoped. Evidence of this pressure are obvious in the 1985 and 1990 farm bills and the work of the coalition attempting to influence the next bill. However, internal dynamics are important too: "alternative" agriculture has become "conventional" in some ways. For example, a survey of state Integrated Pest Management Coordinators showed that at least 40,000 farmers in 32 states have significantly reduced their use of synthetic pesticides (Fernandez, 1994).

Molly D. Anderson is Assistant Professor and Director of the Degree Program in Agriculture, Food and Environment, School of Nutrition, Tufts University, Medford, MA 02155.

The call to research and practice more environmentally benign farming is likely to come now from within mainstream organizations as well as from the outside. The development of alternative agriculture, therefore, is better seen as an interaction among these "external" forces, "mainstream" agriculture, and its own changing state, than as external nudges against a resistant agricultural behemoth.

Acceptance of Alternative Agricultural Research

There has been a dramatic change in acceptance of and interest in alternative agricultural research over the last ten years, from initial skepticism of what was perceived as marginal pseudoscience to enthusiastic support from many quarters. This increased acceptance was linked with the farm crisis of the mid-1980s and the concomitant push to develop less capital-intensive technology, partly to alleviate financial pressure on farmers. It also was linked with the growth of the international environmental movement, which has led to greatly increased public support of agricultural alternatives that can reduce environmental degradation and contamination associated with agriculture.

Another factor contributing to alternative agriculture's acceptance is the wider dissemination of a powerful critique of science and technology. Leo Marx (1992, pp. 450-451) distinguished two extremes on a continuum of attitudes: 1) "irresponsible, anti-intellectual, dismissive views of science held by believers in various populist, quasi-mystical, evangelical, anti-rational religious creeds, and by adherents of pseudosciences such as . . . creationism"; and 2) "serious, rational, intellectually responsible arguments put forward by reputable historians, literary scholars, and philosophers . . . reassessing the conceptual foundations of modern science." Agricultural scientists who criticize agricultural technology and what has been called the "conventional agricultural paradigm" (Beus and Dunlap, 1990) or the "domination paradigm" (Madden, 1994) also belong on this continuum. The defense of conventional agriculture frequently rests on imputations that critics are nearer the former end of Marx's continuum than the latter. However, an interesting development in support of alternative agriculture has been the integration of religious organizations' criticisms of conventional agriculture, based more on spiritual than intellectual concerns, with academic criticism.

Public receptivity to this critique of science and technology has been heightened by major disasters associated with science and technology: malfunctioning, such as at Bhopal and Chernobyl; deliberate misuse, such as environmental abuse by militaristic leaders; and unforeseen costs, such as water pollution by synthetic fertilizers (Marx, 1992). Likewise, public receptivity to alternative agriculture specifically has been enhanced by malfunctions, accidents, and unforeseen costs of pesticides and other agricultural technology (for example, resistance to pesticides, water pol-

lution by chemical spills, and some synthetic pesticides' disruptive effects on the endocrine system).

However, it is important not to overestimate alternative agriculture's acceptance. The awareness of qualitatively changing demands on agriculture and the need for more sustainable use of natural resources that are integral to alternative agriculture are missing from some influential projections of agriculture's future. For example, a national meeting sponsored by the Food and Agricultural Policy Research Institute (FAPRI) in January 1994 to discuss future supplies of major commodities did not include either the environmental impacts *of* agriculture or environmental impacts *on* agriculture. FAPRI's 1994 International Agricultural Outlook assumed that historically average weather conditions and rates of technological change would prevail during the projection period (the present through 2003). This meeting was designed primarily for agricultural economists, representatives of agribusiness and commodity groups, Congressional staff members and U.S. Department of Agriculture personnel. Reinforcing optimistic assumptions among this group that the past will prevail into the future is detrimental to the urgent need for change voiced by advocates of alternative agriculture. As a recent report on soil conservation (Soil and Water Conservation Society, 1993, p. 5) pointed out, " . . . no discussion of the future of agriculture can responsibly ignore . . . environmental and resource conservation issues."

A 1989 survey of 920 doctoral scientists with experiment station appointments in biologically related fields at U.S. colleges of agriculture assessed their opinions and contributions to issues central to alternative agriculture (Buttel and Curry, 1992). Fewer than half believed their research contributes strongly to improving the quality of the agricultural environment (42% were above 3 on a five-point Likert scale ranging from "no importance" to "great importance"), to reducing pollution problems caused by soil erosion and runoff (22%), to increasing agricultural sustainability (32%), or to reducing use of pesticides and fertilizers (30%). Similarly, fewer than half stated that their research frequently contributes to important social issues that have influenced public interest in alternative agricultural research: farmer and farmworker health issues (15% were above 3 on a five-point scale from "rarely" to "frequently"); energy issues (19%); environmental issues (36%); and more generally, alternative approaches to agriculture (26%).

The findings of this comprehensive survey were reinforced by a survey conducted the following year of agricultural research projects using the terms "sustainable" or "low-input" in their titles or abstracts in the CRIS database, or funded in the last few years by "low-input" or sustainable agriculture research programs (Anderson and Lockeretz, 1992). Few of the 122 projects showed the broad scope that writing about alternative agricultural research emphasizes. Only 22% dealt with entire farms, 25% looked at both crops and livestock, and 19% studied general processes from which basic agroecological principles could be learned. Although 44% measured environmental effects, only 7% analyzed off-farm social and economic effects.

Further evidence of the lack of infiltration of "alternative" research into mainstream research institutions is provided by recent federal hearings and reports by governmental and non-governmental organizations (for example, Bird and Hassebrook, 1992; General Accounting Office, 1994; U.S. Senate, 1994). There have been only slight adjustments in the Agricultural Research Service's priorities over the last ten years: most funds are still devoted to agricultural productivity, while "system integration" and "soil, water and air" studies have remained at just 2% and 13%, respectively, of the total research budget. Similarly, funds in the Cooperative State Research Service's Competitive Grants Program still go mainly to traditional plant and animal research (General Accounting Office, 1994).

What do these surveys and funding patterns indicate about where alternative agricultural research is in its life cycle? Buttel and Gillespie (1988), placing alternative agriculture within the context of other emergent research programs that serve as symbols of social movements, suggested a general pattern in which symbols first are formed and crystallized by dissident groups as a challenge to the legitimacy of dominant institutions. Next, these institutions respond by appropriating the symbol and demobilize the movement by trivializing it, smothering it with bureaucracy, or otherwise creating the impression that the problem has been solved. This results in a crisis for activist groups that originally promoted the cause, in that they must decide whether to focus on another symbol that has not been diluted, or try to wrest back the original symbol.

Each of these steps is happening now, with different regions and institutions at different stages. For alternative agricultural research as a whole, dominant institutions have appropriated the field through the strong reorientation of a few disciplines (agronomy, horticulture and entomology); by connections with existing research/extension programs such as Integrated Pest Management; by support for prior social causes, such as serving the family farm; and by extending and rejuvenating applied, client-oriented research programs (Buttel and Curry, 1992). This appropriation has been very broad, with sustainability espoused as a dominant goal by corporations such as Monsanto and by nongovernmental organizations and colleges of agriculture. As the studies and funding patterns reported above show, however, the rhetoric has overreached real changes in research and development of appropriate technology.

Symbols serve to quiet conflict: "Emotional commitment to a symbol is associated with contentment and quiescence regarding problems that would otherwise arouse concern" (Edelman, 1964, p. 32; quoted and related to agricultural symbolism by Youngberg et al., 1993). Appropriation of the symbol of alternative agriculture by dominant institutions has diluted and weakened its power, and some conflicts that it temporarily smoothed are breaking open. Advocacy organizations have responded by saying, in effect: "This isn't what we meant: alternative agricultural research is more than increased efficiency of pesticide use, rotational grazing, or better soil erosion control. Each of these can be significant in its own right, but they are not enough, either singly or in aggregate." As the symbol and its clout have become diminished by appropriation and dilution, the advocates who originally led academics to sustainable or alternative agriculture must decide whether to continue working under these names, or strive to reach their goals within other programs such as improved water quality or rural community development.

Like environmental groups more generally, advocacy organizations in alternative agriculture show growing sophistication in

their use of research and in the ways they are working to influence agricultural policy. Examples include the evaluations of national research policy by the Center for Rural Affairs, the work of regional sustainable agriculture working groups, and the National Dialog supported by the National Sustainable Agriculture Coordinating Council in spring, 1994. The power of advocacy organizations rests on growing public demand for changes in agriculture and farmers' dissatisfaction with the outcomes of conventional agricultural research. These sources of legitimacy, combined with improvements in political strategies, should allow alternative advocacy organizations to continue to gain power relative to conventional agricultural organizations.

The life cycle of alternative agricultural research can be seen in microcosm with research and development in individual areas, such as agricultural biotechnology. Initial attention by agribusiness corporations and agricultural research institutions on practices and technical possibilities or solutions was followed by analysis of domestic and international biological, ecological, and social effects. This analysis was conducted by many people and organizations, but non-governmental organizations such as Rural Advancement Foundation International took the lead. Policy recommendations came from these critical analyses, in opposition to federal approval of product registration applications.

This does not imply that technological breakthroughs drive science, nor that science drives policy. The relation of technology to both applied and "basic" science is complex and non-linear, and science is a relatively weak component of policy decisions. However, new technology is difficult to stop once it has been developed, even if there is considerable social ambivalence about it. There are no precedents in agricultural technological development for labor-saving profitable technology to be rejected merely because of its likely unpalatable social consequences, such as driving some farmers out of business or contributing to the collapse of rural economies. This development process has unfolded, amid much public criticism, with bovine somatotropic hormone: the criteria for granting approval to Monsanto to sell the product were the safety of humans, animals and the environment, not its social desirability.

Where Should Alternative Agricultural Research Go?

Three overriding concerns must be heeded to answer this question: 1) whether sustainable agriculture can be attained merely by refining conventional agriculture; 2) what role society wants agriculture to serve beyond food production; and 3) how agricultural research will incorporate social issues such as equitability of access to food, farmland, and positions of power within agricultural institutions. This paper deals with the last of these, which requires examining not only alternative practices themselves but also how particular practices and combinations of practices affect different segments of the population.

For both individual technologies and alternative agriculture as a whole, the social problems seem far more challenging than the technical problems. Their solution requires collaborations of natural scientists, social scientists, farmers, farmworkers, policy analysts, policy makers, agribusiness representatives, and diverse public interest groups. Four stages of movement toward alternative agriculture can be distinguished (Fig. 1); these stages form a cycle

Figure 1. Stages of Alternative Agriculture.

Stage	Questions	Analyses	Participation Needed	Product
1	What are the current environmental, health, and social effects of agricultural systems? (What ARE we doing?)	• consequences of current agricultural systems • comparisons of consequences among different systems	• physical, biological and agricultural scientists • medical researchers • social scientists • public interest groups • farmers	comprehensive understanding of effects of mainstream agriculture and the need for alternatives
2	What is technologically possible? (What CAN we do?)	• development of alternative agricultural practices • environmental and productivity consequences of these practices	• agricultural scientists and engineers • agribusiness • farmers	array of alternative practices
3	What is politically and socially possible? (What CAN we do?)	• social and health consequences of alternative practices developed in Stage 2 • consequences of conversion to systems using these practices	• policy analysts • public interest groups • social scientists	articulation of different scenarios of agricultural policies and practices, and their consequences
4	What is socially desirable? (What SHOULD we do?)	• effective ways to ensure broad participation in decisionmaking on agricultural policy	• policy makers • public interest groups • agribusiness • consumers; the public • farmers and farmworkers • social scientists (to study improved decisionmaking and evaluation of choices)	social vision and decision among alternative scenarios

because decisions implemented in Stage 4 are evaluated and adjusted by spiralling up to a new Stage 1. Researchers have important roles particularly in Stages 1 through 3. The scientific contribution in alternative agriculture has been strongest in the second stage; the contributions of science have barely been outlined in the third and fourth stages. In the gaps between the creation of technological possibilities (Stage 2), the articulation of alternative strategies for using them (Stage 3), and the decision of what we as a society should do with them (Stage 4), social sciences have lagged behind agronomic and natural sciences, to the detriment of advancing alternative agriculture.

It follows that several critical areas are not being addressed and need more attention from researchers, and the policy makers who influence research, for alternative agriculture to compete successfully with mainstream agriculture. The remainder of this paper stresses two points: 1) alternative agricultural research needs a stronger grounding in social sciences; and 2) it must expand beyond food production to examine the entire food system.

Agricultural research and social sciences

Agriculture, like all resource management, is an interaction of people both with people and with the environment, not just the latter (and certainly not just the impacts of people *on* the environment). Ludwig et al. (1993, p. 36) argued that "resource problems are not really environmental problems. They are human problems that we have created at many times and in many places, under a variety of political, social and economic systems." The principal danger of leaving out the social side of resource management is that manipulating and managing the environment become paramount, rather than improved understanding and management of people. This point seems obvious, yet the necessary integration of social and natural sciences seems radical to some people. Another article in the same volume of *Science* as that of Ludwig et al. (Stern, 1993) advocates a "new" environmental science that would include human-environment interactions. Given that this need has existed for a long time and that many scientists have been attempting to address it, why does an author in a prestigious journal that purports to cover all of science consider it new? And, more to the point here, why has the study of these interactions made few inroads into alternative agriculture?

The conclusion is not simply that more social science is needed in alternative agricultural research. The foci of social science research in this area, with some notable exceptions, have been on farmers' adoption of innovations, economic comparisons of alternative systems, the definition of sustainable agriculture, and consumers' opinions. These are valuable in understanding the demand for alternative agriculture and its basic scope, but less adequate in understanding its social implications and its potential under various scenarios (vital information for Stages 3 and 4 of Fig. 1). Social science is especially crucial now to help develop and explore the ramifications of thoroughly restructuring agricultural systems to make them congruent with the aim of sustainability, rather than just tinkering with conventional systems.

Research on the whole food system

The food system includes food processing, preservation, distribution, consumption, recycling, and waste disposal, both in the United States, regionally, and globally. Natural and social sciences are needed to examine the components of this system. In the framework of Fig. 1, why do present patterns exist, what options are politically feasible, what would be the biophysical and social consequences of those options, and which of these options should society implement widely?

A small band of gadflies has hovered around agriculture for several decades, claiming that agricultural research, and alternative agricultural research more specifically, has too narrow a focus (see several papers in Allen, 1993, for succinct and creative insights on the history and implications of this claim). This call is kin to the familiar assertion that ecological aspects of agriculture must be examined holistically, looking beyond the usual boundaries of the system of interest.

Specific examples follow of the constituencies and issues that would influence alternative agricultural research more if it expanded to an examination of the entire food system rather than emphasizing agricultural production. Some work is being done on almost all these issues, but they are peripheral to the main efforts of agricultural research. A thorough understanding of these constituents, and answers to the dilemmas implicit in each of these issues, will require the collaborations mentioned earlier of scientists, policy makers, farmers, businesses, and representatives of public interest groups.

Examples of constituents

The public as consumers. Consumer education and consumer advocacy are very important elements of alternative agriculture, yet the national Sustainable Agriculture Research *and Education* (SARE) program presently does not encompass education beyond farmer extension. SARE has been a highly successful component of alternative agriculture in the last decade (General Accounting Office, 1992); it would be an excellent vehicle for moving research into the areas recommended here. One type of research that could profoundly affect alternative agriculture is on ways to encourage consumers to accept produce from alternative farms. This is as vital as assessing what consumers are willing to pay right now for such products, which has been researched much more thoroughly. Other consumer issues that affect alternative agriculture are urban food production and household production (estimated by the National Gardening Association in 1989 at $18 billion worth of fruits and vegetables); how to reconcile the conflicting demands for fewer pesticides and more processed, perfect-looking foods; and the incongruence between nutritional advice and environmental prudence (for example, increasing consumption of fish at a time when world fish stocks are declining).

The public as political advocates. The demand for greater citizen participation in agricultural research and the role of advocacy could be understood better with the tools of social science, drawing on previous work with social movements. We do not understand well enough how public concern about agricultural products and practices (for example, the use of pesticides and the humane treatment of farm

livestock) arises, develops, and influences public policy. Many groups in the sustainable agriculture coalitions have advocated successfully for policy changes, but their work has not been studied intensively.

Unconventional farms and farmers. These include small-scale growers, growers of minor crops, organic farmers, women, minorities, and institutional farms. Research on these groups, both in alternative and mainstream agriculture, has been overshadowed by research on major commodities and on white, male farmers. Partly for this reason, some shocking inequities have received too little attention, such as the attrition of black farm operators, which has far exceeded white attrition. For example, in 1987 there were 41% as many white farmers as in 1900, but only 3% as many black farmers (Demissie, 1990). "Alternative" agriculture is by definition unconventional, but some farmers and farming systems are more unconventional than others. A system of allocating research attention to those farmers and alternatives that are most prominent, numerous, or successful is not necessarily the best for meeting social demands or finding the "best" alternatives in different circumstances.

Farmworkers. Research on the health effects of agricultural practices has contributed to public support of alternative agriculture, yet the population that is most vulnerable and least able to protect itself has been neglected. The risks that traces of pesticide residues on fruits and vegetables create for middle-class children has attracted much more political and research interest than the direct exposure to contaminants in the field by farmworkers and their children who must accompany them to work.

Examples of issues

International implications of alternative agriculture in other industrialized and developing countries. Agenda 21 (United Nations, 1993) outlined the premises of sustainable development; sustainable agriculture has to be at the center of such development. The crises of industrialized agriculture worldwide are apparent in the decreasing response of many crops to the inputs that have contributed most to yield increases over the last few decades (Brown, 1994) and in the array of environmental problems associated with industrialized agricultural systems. Human health effects of industrialized agriculture are being elaborated rapidly in developing and industrialized nations. In addition, the relations between food security and regional violence are becoming clearer (Homer-Dixon, 1991).

Agriculturists and policy makers in the United States could benefit from the experience of those in other industrialized and developing countries. For example, what methods of encouraging sustainable use of agricultural resources have been most successful in Farming Systems Research and indigenous activist organizations? What can U.S. policymakers learn from the way various European countries have sought to preserve the countryside and support agriculture, and how much of this work is applicable to the United States?

Connections between alternative agriculture and other food production systems, including aquaculture, mariculture, and agroforestry. World grain production per capita has declined since 1984 and is projected to continue declining at least until 2030; world marine fish catch per capita also is projected to continue declining from its 1989 peak (Brown, 1994, summarizing USDA and Food and Agriculture Organization data). Fish farming has been promoted as an alternative to marine fishing, but as currently practiced, it has many environmental problems (Kane, 1993). Alternative agriculture is only part of the solution to feeding a growing population, and it needs to develop in concert with other environmentally viable production methods.

Integration of alternative agriculture with the rest of the food system. Less environmentally damaging, more socially equitable, and healthier alternatives are available in food processing, distribution, waste disposal and recycling. Several innovative programs already exist to meet people's food needs in ways that consume less energy and nonrenewable resources. Many of these programs have outstanding social benefits too. For example, the Food Project, formerly part of the Massachusetts Audubon Society, hires teams of high school students from both low-income urban neighborhoods and wealthy suburbs of Boston to raise organic food, then distribute it to shelters and low-income neighborhoods. Community-supported agriculture, in many variations around the country, allows farmers and customers to negotiate their terms and work together. A volunteer-run program in a suburb of Boston composts all food waste from a public elementary school in a community garden on adjoining land, where school children learn about nature and food production by gardening. Such programs are small-scale, personalized, local alternatives to the domination of food production and provision by large corporations. They are being encouraged and supported by private foundation funds and by donations from community businesses and volunteers. Research attention could help them be initiated and maintained more effectively and could show which features are common to successful programs.

Political strategies. How can advocates of alternative agriculture working at different levels best integrate their efforts? These levels range from city councils and regional planning boards to national coalitions and international organizations. Which level of action is most appropriate for advancing each aspect of sustainability?

Potential for linkages with institutions and movements dealing with other social problems. This possibility applies to connections with religious organizations, the international environmental movement, and organized efforts to combat hunger and poverty. Many have already gained a great deal of public support and credibility, and alternative agriculture could benefit by closer alignment with them on shared issues.

One part of the final example deserves special attention: the potential for systems that benefit both growers practicing alternative agriculture and populations that need food. Many successful collaborations exist between farmers practicing alternative agriculture, or alternative agriculture advocates, and public or private food assistance programs. For example, coupons from the Special Supplemental Food Program for Women, Infants and Children (WIC) can be used in some farmers' markets, and several initiatives listed above provide food from growers at the ur-

ban fringe to feed inner-city shelter dwellers and supplement emergency food banks. However, connections are needed in every city and community between farming systems that help to heal environmental abuses and food distribution systems that help to heal social disintegration. The urgency and practicality of such solutions would become much more apparent if alternative agriculture encompassed the entire food system and complemented natural science and agronomic studies with studies of their social implications.

Why Aren't We There Already?

It is futile to list neglected constituents and issues without thinking why they have been given short shrift in alternative agriculture research. One barrier is the people doing the research and administering research funds. Agricultural research is conducted by a relatively homogeneous group that only recently has begun to diversify. It is still overwhelmingly white and male: 93% of employed doctoral agricultural scientists in 1989 were white and 93% were male, although 21% of agricultural science doctoral degree recipients in 1989 were female (White, 1992, pp. 81, 156, 158). This homogeneity of researchers contributes to a fairly narrow definition of what is important. Furthermore, older researchers tend to come from farm backgrounds (Busch and Lacy, 1983, p. 54) and are likely to share the more conservative political opinions of their cohorts. This is changing, but younger or less conservative researchers and administrators usually have relatively little power in agricultural institutions. Of course, many white, male researchers, both older and younger, have been instrumental in advancing alternative agriculture. Often their effectiveness is enhanced by the rapport they have with farmers and their long-standing familiarity with agricultural institutions. However, a homogeneous research establishment is vulnerable to miscommunication with those outside the mainstream, despite the good intentions of researchers, because they have fundamentally different perspectives. This means researchers may have trouble hearing and understanding what people on the outside are saying.

A second barrier results from the way agricultural institutions operate. Mainstream agricultural institutions have deep ties with traditional agriculture and are sympathetic to these interests. Also, there is still a large disparity between the academic value of social and natural sciences, which leads to difficulties in bridging the cultural and institutional gaps between them. Pretending that social science is not "really" science, or is not as important as natural sciences, obstructs the ability to understand the consequences outside universities and disciplinary journals of developments in all sciences.

A third barrier is the constellation of attitudes dominating American society. The emphasis on technological innovation, "progress," and competition leads to an emphasis on farmers who adopt technological innovations and are financially successful. Researchers and policymakers may overlook the possibility of collaborative win-win solutions, especially when these involve improvements in the status of groups that historically have been "losers" by these criteria (see examples of specific programs above).

Other important parts of American ideology are individualism and the related belief, on which our economic system rests, that the promotion of self-interest is rational behavior leading to a better life for all. The American legal system and social mores are based on rights such as life, liberty, and the pursuit of happiness; but they neglect the companion responsibilities of each of these rights. These beliefs and attitudes contribute to resistance to social planning, and they are barriers to proceeding with Stage 4 in Fig. 1. Americans are curiously reluctant to talk about, much less work out, the kind of agriculture we as a society want to maintain and create.

Conclusions

Some would argue that the barriers to building a stronger groundwork of social sciences in alternative agriculture and to focusing on the entire food system rather than food production are so overwhelming that the effort to make these changes is not worthwhile. Don't researchers have enough to do already?

There are four compelling reasons for broadening alternative agricultural research. First, it cannot continue to neglect the full constituency of alternative agriculture and the full range of social ramifications and potential because simple justice requires more equitable distribution of "goods" from the publicly supported agricultural research system. The American public will not continue indefinitely to fund a system that perpetuates inequities. With the United States and the entire world becoming increasingly polarized into "haves" and "have-nots," public policies that contribute to this polarization are sure to backfire eventually. Those who have not benefitted from public investment in agriculture will eventually become the majority, and force changes willy-nilly.

Second, the scope of alternative agricultural research must be broadened to meet its goals. One way to enlarge that scope is to bring social dynamics and the entire process of supplying food into the picture. Many of the reasons that research on agroecosystems is needed to complement crop research also apply to why research is needed on the societies within which food systems and agroecosystems are designed and embedded. By understanding the dynamics of the next higher level in a hierarchy, the dynamics of the level we are trying to manipulate or comprehend can be grasped more thoroughly.

Third, forging a workable, socially acceptable agriculture requires improving its relevance to social needs and sustaining a conversation with its constituents outside the establishment. The desired conversation will not be two monologues going on simultaneously: criticism from outsiders, and academic discourse that only interests other academics from those on the inside. Rather, it must be a true dialogue in which we as a society build something better than what either side can envision on its own.

Finally, creating a stronger public and political base for alternative agriculture can come about by linking its mission with other social movements and finding common ground among them. In this way, alternative agriculture can be part of a better future for people and the world, and not just offer new technologies that perpetuate the inequities and indignities that have evolved within industrialized agriculture.

References

1. Allen, P. (ed). 1993. Food for the Future. Conditions and Contradictions of Sustainability. John Wiley & Sons, New York, N.Y.
2. Anderson, M.D., and W. Lockeretz. 1992. Sustainable agriculture research in the ideal and in the field. J. Soil and Water Conservation 47:100-104.
3. Beus, C.E., and R.E. Dunlap. 1990. Conventional versus alternative agriculture: The paradigmatic roots of the debate. Rural Sociology 55:590-616.
4. Bird, E., and C. Hassebrook. 1992. Report card on USDA research policy. Center for Rural Affairs, Walthill, Nebraska.
5. Brown, L.R. 1994. Facing food insecurity. In L.R. Brown and the Staff of Worldwatch Institute (eds). State of the World 1994. W.W. Norton and Company, New York, N.Y. pp. 177-197.
6. Browne, W.P. 1988. Private Interests, Public Policy, and American Agriculture. Univ. Press of Kansas, Lawrence.
7. Busch, L., and W.B. Lacy. 1983. Science, Agriculture, and the Politics of Research. Westview Press, Boulder, Colorado.
8. Buttel, F.H., and J. Curry. 1992. The structuring of sustainable agriculture in public research institutions: Results from a national survey of land-grant agricultural scientists. Impact Assessment Bull. 10:7-26.
9. Buttel, F.H., and G. Gillespie. 1988. Agricultural research and development and the appropriation of progressive symbols: Some observations on the politics of ecological agriculture. Bull. 151. Dept. of Rural Sociology, Cornell Univ., Ithaca, New York.
10. Demissie, E. 1990. Small-scale Agriculture in America: Race, Economics, and the Future. Westview Press, Boulder, Colorado.
11. Edelman, M. 1964. The Symbolic Uses of Politics. Univ. of Illinois Press, Urbana, Illinois.
12. Food and Agricultural Policy Research Institute. 1994. FAPRI 1994 international agricultural outlook. Staff Report 2-94. Iowa State Univ., Ames, and Univ. of Missouri, Columbia.
13. Fernandez, M.D. 1994. Pesticide use reduction assessment. Committee on Agriculture, Nutrition, and Forestry, U.S. Senate, Washington, D.C.
14. General Accounting Office. 1992. Sustainable agriculture. Program management, accomplishments, and opportunities. GAO/RCED-92-233. Washington, D.C.
15. General Accounting Office. 1994. Agricultural research. Refocusing priorities to meet current concerns. Testimony by Robert A. Robinson before the Subcommittee on Agricultural Research, Conservation, Forestry, and General Legislation, Committee on Agriculture, Nutrition, and Forestry, U.S. Senate. GAO/T-RCED-94-45. Washington, D.C.
16. Hadwiger, D.F. 1982. The Politics of Agricultural Research. Univ. of Nebraska Press, Lincoln.
17. Homer-Dixon, T.F. 1991. On the threshold: Environmental changes as causes of acute conflict. International Security 16(2):76-116.
18. Kane, H. 1993. Growing fish in fields. World Watch 6(5):20-27.
19. Ludwig, D., R. Hilborn, and C. Walters. 1993. Uncertainty, resource exploitation, and conservation: Lessons from history. Science 260:17,36.
20. Madden, P. 1994. Goals and realities of attaining a more sustainable agriculture. Speech posted on the Sustainable Agric. Network, 11 May 1994, by the World Sustainable Agric. Assoc. (wsaa@igc.apc.org).
21. Marx, L. 1992. Environmental degradation and the ambiguous social role of science and technology. J. History of Biology 25:449-468.
22. National Gardening Assoc. 1989. National Gardening Fact Sheet. Burlington, Vermont.
23. Soil and Water Conservation Society. 1993. Understanding the human element in agricultural resource conservation. Ankeny, Iowa.
24. Stern, P.C. 1993. A second environmental science: Human-environment interactions. Science 260:1897-1899.
25. United Nations. 1993. Earth Summit: Press summary of Agenda 21. New York, N.Y.
26. U.S. Senate. 1994. Setting agricultural research priorities and proposed means of implementation. Senate Hearing 103-415.
27. White, P.E. 1992. Women and minorities in science and engineering: An update. NSF 92-303. National Science Foundation, Washington, D.C.
28. Youngberg, G., N. Schaller, and K. Merrigan. 1993. The sustainable agriculture policy agenda in the United States: Politics and prospects. In P. Allen (ed). Food for the Future. Conditions and Contradictions of Sustainability. John Wiley & Sons, New York, N.Y. pp. 295-318.

National Poll Finds "Broad-Based Support" for Pesticide Reduction

Almost two-thirds (64%) of all voters questioned by a new poll agreed that "the government should use existing financial subsidies to reward those farmers who take steps to keep chemical pesticides from polluting food and water, because these chemicals can be harmful to people, especially children," according to Peter D. Hart Research Associates, Inc.

"Support for pesticide reduction is broad-based, even among people who describe their area as a rural or farming community (57%) and among those who live in the Agricultural Midwest (59%)," according to the company's poll of 1,201 registered voters who said they voted in November. "Three in five Republican candidate voters (58%) support the argument for pesticide reduction." Just 24% agreed that "the government should not use existing financial subsidies to reward those farmers who take steps to keep chemical pesticides from polluting food and water, because without these pesticides, crop production could go down, less food would be produced, and consumers could end up paying higher prices."

In addition, the poll found that "voters demonstrate that they do not want to roll back environmental protections." The voters polled are "more than twice as likely to say the current laws and regulations for protecting the environment don't go far enough (41%) as they are to think those laws go too far (18%)." People who say they voted for a Republican congressional candidate believe current environmental protection laws don't go far enough, rather than go too far, by 34% to 25%; 50% of those who say they voted for a Democratic candidate believe those laws don't go far enough; 20% overall felt they strike the right balance.

Making alternative agriculture research policy

Katherine Reichelderfer Smith

Abstract. *The policies influencing the American agricultural research agenda are developed by Congress, the U.S. Department of Agriculture, and the 58 state agricultural experiment stations of the land-grant university system, with input from various advisory groups. Despite the slow pace of change in the agricultural research agenda, there are no special barriers keeping the research system from adapting to contemporary and alternative agriculture issues. Rather, agricultural researchers have neither appropriate professional incentives nor sufficient financial incentives to shift toward alternative agriculture. Public intervention to alter these incentives has been thwarted because agricultural research institutions set their agendas through obscure processes. Five areas of policy change that could improve the prospects for evolution of a significant alternative agriculture research agenda are: 1) imposing a means test for formula fund payment limitations to states, with saved funds directed toward alternative agriculture research; 2) making priority setting a condition for receiving federal funds for agricultural research to make the research agenda-setting process clearer to all interested parties; 3) requiring that federally funded research programs be categorized by the specific social goals toward which they are directed, to aid in judgments about the relevance of specific public agricultural research programs; 4) requiring information on research programs to be reported in a way that is specifically relevant to the alternative agriculture agenda; 5) formally involving public citizens and farmers in reviewing agricultural research grants to assure that the usefulness of proposed research is weighed along with scientific merit. These proposals complement current interest in making science generally more responsive to national priorities, and are entirely feasible within current agricultural research policy processes. Their effectiveness, however, is limited by the shrinking influence of federal funding in the state agricultural experiment station system, and they are only incremental changes within the existing system rather than radical reforms toward an alternative research system.*

Key words: agricultural research, competitive grants, Current Research Information System, formula funding, peer review, research policy, science policy, state agricultural experiment stations

Introduction

There is substantial concern that the American agricultural research system does not adequately advance agricultural sustainability. The system has been criticized on several counts: that the discipline-specific orientation of agricultural research is inadequate for resolving complex, contemporary problems (Holt, 1989); that the commodity-specific focus of agricultural research maintains a bias toward "productivity gains at any cost," precludes the systems orientation inherent in alternative agricultural approaches, and devotes inadequate funding and attention to agroecological studies (Buttel, 1985); that the system largely addresses the treatment rather than the prevention of agricultural and agroenvironmental problems (Rodale, 1989); that there is no system of accountability to judge the social impacts of new technologies before investing funds in their pursuit (Buttel, 1985); and that agricultural research tends to confine itself to the current, increasingly industrialized food and agricultural system, rather than on possibilities for shifts in the evolution of that system (Hassebrook, 1989; Bird, 1993).

Consequently, there have been increasing calls for reexamination and change in agricultural research policy (Consortium for Sustainable Agriculture Research and Education, 1994). This article addresses the extent to which research policy affects the advancement of alternative agriculture, and offers some ideas for revising and reforming it. Here, I review current agricultural policy: who makes it, at whom is it directed and to what ends, and how effective is it in influencing what gets investigated and how?

Who Makes Agricultural Research Policy?

Agricultural research policy is made in part by Congress, in part by USDA, and in part by the state agricultural experiment stations (SAES). The simplistic model of agricultural research policymaking proceeds along the following lines.

1. The Agriculture committees of Congress authorize and direct federally funded research in general ways under the research and education title of the farm bill.
2. The Agricultural Appropriations subcommittees refine authorizations by determining how federal funds are allocated to specific research agencies, institutions, projects, or facilities.

These congressional committees and their members may be influenced in several ways: by Executive Branch research planning documents and budget proposals; by the Experiment Station Committee on

Katherine Reichelderfer Smith is the Director of the Policy Studies Program, Henry A. Wallace Institute for Alternative Agriculture, 9200 Edmonston Road, Suite 117, Greenbelt, MD 20770-1551.

Organization and Policy (ESCOP), which periodically prepares a summary of research priorities across experiment stations; by the recommendations of several advisory boards established by Congress in 1977 (more about them later); and by individual representatives of universities, commodity groups, and public interest groups seeking support for specific research projects or priorities.

3. Once the bounds of operation have been set by Congress, USDA makes specific policy decisions within those bounds that determine the direction of its research agencies' programs, the mechanisms by which competitive grants for agricultural research will be allocated, and how any congressional mandates will be carried out.
4. Meanwhile, a highly decentralized process of research policy decisionmaking is taking place within the state agricultural experiment stations. Upon receiving formula funds, each station decides, however it wishes, with no guidelines or mandate for consistency, whether to direct the use of those funds, and if so, how. The availability of competitive funds for specific purposes also influences experiment station decisionmaking.

Over the past two decades, each step in this process has received scrutiny and experienced some change. In the 1970s, a series of influential reports stimulated debate about the agricultural research system and about how federal policy could encourage improvement in that system. The "Pound Report" (National Research Council, 1972) concluded that agricultural research quality was low and that this was due to the design of the research system and its focus on commodities. Ten years later, this message was reinforced by the so-called "Winrock Report" (Rockefeller Foundation, 1982), which cited the system's dependence on formula funding as a reason for the low quality of much agricultural research, and promoted basic research through public-private research partnerships.

Meanwhile, Jim Hightower's *Hard Tomatoes, Hard Times* (1973) had raised the public's consciousness about agricultural research by charging in popular language that the agricultural research system was far more responsive to commercial interests than to the needs of small farmers, farm workers, or food consumers. These reports, their various offspring, and the intensive public debate that accompanied them led to several significant changes in agricultural research policy of congressional origin.

Significant congressional actions

Although it was enacted only 18 years ago, the Food and Agriculture Act of 1977 included what Rep. George Brown, one of its crafters, called "the first comprehensive attempt to update the social contract between the agriculture research and education system and the broader society" (Brown, 1994, p. 3). Title XIV created the Joint Council for Food and Agricultural Sciences and a National Agricultural Research and Extension Users Advisory Board (UAB) as mechanisms for insuring better coordination between state and federal research planning and improved incorporation of users' needs into research planning and agenda-setting. The Joint Council is "a forum for debate and consensus building on significant issues involving the agricultural and food sciences" (National Research Council, 1989, p. 139). Each year it issues a report on agricultural research priorities as guidance to USDA and the land-grant colleges of agriculture. UAB is composed of farmers and ranchers, private sector scientists, agribusiness representatives, state and local government officials, and users of the output of the federal and federally influenced agricultural research system. UAB's mandate is to review Executive Branch Budget proposals related to agricultural research and make recommendations that reflect users' perspectives. UAB reports to both Congress and USDA. Theoretically, the Joint Council and UAB are conduits for input on the agricultural research agenda from producers and others who want to see more money invested in alternative agriculture research. However, the members of these committees are political appointees of the Executive Branch. Therefore, the extent to which they represent "outside" input depends on the administration.

The Food and Agriculture Act of 1977 included another significant agricultural research policy change that has implications for current research policy. Title XIV formally established a Competitive Research Grants Program under the direction of USDA's Cooperative State Research Service (CSRS). This has greatly affected the proportion of federal funds allocated to state agricultural experiment stations with restrictions on subject matter. In 1981, approximately 83% (calculated from Huffman and Evenson, 1993, Table 4.3, p. 105) of CSRS funds were allocated to experiment stations through formula funding mechanisms based on each state's land use and population, without requirements to devote those funds to specific agricultural research purposes. By 1992, this share had dropped to 57%, with special grants (those made directly by Congress through appropriations bills for specific purposes) accounting for about one-fourth and competitive grants (for specific purposes) accounting for about 18% of all CSRS funding to the states (Nicole Ballenger, National Research Council, personal communication, 1994). Formula funding as a proportion of total federal funding for agricultural research is definitely decreasing because of a conscious policy decision. This trend could allow greater direction of federal agricultural research funds to support alternative agriculture. Whether that happens, however, will depend on what research areas are designated for competitive grants programs and how those programs are administered.

The Food Security Act of 1985 was especially significant for alternative agriculture because it authorized a special research program in Low Input Sustainable Agriculture (LISA). The 1988 appropriations bill funded that initiative, thereby mandating the LISA program in USDA. Although the $3.9 million appropriated in 1988 for the LISA program represented less than 2% of the funds made available by USDA for agricultural research, it sent a significant message about the importance Congress placed on alternative agriculture research.

That message was underscored in the Research and Education title of the last farm bill, the 1990 Food, Agriculture, Conservation and Trade Act (FACTA), which authorized the Sustainable Agriculture Research and Education (SARE) Program. The SARE program is a renamed LISA program with more explicit requirements for CSRS and the Extension Service to in-

itiate and develop sustainable agriculture research and education programs. FACTA further directed that when designing procedures for awarding competitive grants, CSRS was to give heavy weight to how much the proposed research contributed to sustainable agriculture goals. That directive was particularly significant in that FACTA also established, under the National Research Initiative (NRI) Competitive Grants Program, USDA's largest fund for competitive grants for specific areas of agricultural research. The broad subject areas under which NRI competitive grants can be made and the total amount of funds and their allocation among subject areas are designated by Congress. Besides stressing the need to support sustainable agriculture approaches, FACTA also directed NRI program administrators to put a high priority on "mission-linked" and "multidisciplinary" research, both of which have great potential for furthering alternative agricultural research.

Because the USDA-SAES system that conducts most public agricultural research influences these congressional actions and exercises considerable discretion in how they are implemented, it is misleading to view Congress as acting entirely independently. Still, Congress has been more explicit than USDA and the SAES system concerning both agricultural research policy in general and alternative agriculture research in particular.

The land-grant universities and the state agricultural experiment stations

The land-grant university system influences federal agricultural research policy mainly through the Experiment Station Committee on Organization and Policy (ESCOP), one of several academic committees of the National Association of State Universities and Land Grant Colleges. ESCOP annually conducts an agricultural research budget review and priority setting exercise, reporting its findings and recommendations both to USDA and to Congress. The budget review and recommendations of ESCOP have proved especially important, since CSRS uses the ESCOP budget as a primary basis for its own budget recommendations for inclusion in the Administration's annual budget request to Congress. Since Congress has already been primed through direct interaction with ESCOP, that committee's recommendations also hold considerable weight in the congressional appropriations decisions that follow.

Ironically, ESCOP activities are likely to have a much more substantial influence on how and to what purpose federal agricultural research funds are allocated than on how agricultural research agendas are set at the SAESs, which receive all formula funds and the bulk of competitive grants. Theoretically, the research priorities of the SAES system are incorporated in and responsive to ESCOP recommendations. However, ESCOP priorities are typically so broad and all-encompassing that it is easy to fit any research project under one of its priority designations.

The real agricultural research policy decisions for the SAESs are made at the experiment station level. The 58 SAESs have approximately 58 different models for doing this. A few, notably Rutgers' Cook College and the New Jersey Agricultural Experiment Station, are very specific concerning subject matter and research goals supported with Hatch funds (formula funds first authorized under the 1887 Hatch Act) and state matching funds. Others rely on broad, general mission statements to guide competitive funding requests from experiment station scientists. Many do not use a competitive process at all. Instead they apply these funds toward the salaries of faculty members with experiment station appointments.

USDA's research policy

USDA makes policy decisions that affect the scope and direction of research conducted both by its in-house research agencies, which include the Agricultural Research Service (ARS), the Economic Research Service (ERS), and various units of the Forest Service, and of research funded through CSRS by various mechanisms.

In-house research is directed by the agencies' annual work plans and guided by multiyear program plans. How these plans are developed and what criteria they are based on are unclear, and are perceived by users of agencies' research products as unsystematic (Charles Valentine Riley Memorial Foundation, 1994). Phillips (1990) observed that USDA lacks a mission statement for its agricultural research system, has no mechanism for coordinating research activities among its agencies, does not set clear and specific priorities, and has not sought to reconcile or respond directly to the priorities recommended by its various advisory groups.

Regardless of whether USDA research agencies' programs result from conscious science policy, their activities add up to a program that to varying degrees can contribute to alternative agriculture knowledge. A 1993 review of ARS programs found that 21 of 1,177 ARS research projects, representing about 1% of the agency's total research budget, qualified as "fully sustainable" agriculture research based on an experimental research assessment protocol (Consortium for Sustainable Agriculture Research and Education, 1994). Nevertheless, nearly one-third of the projects were found to "contribute to sustainability," and only about 6% were judged to "detract from sustainability" (Consortium for Sustainable Agriculture Research and Education, 1994). The assessment protocol, developed by USDA in response to a congressional request to review ARS's sustainable agriculture program, is controversial. However, in 1994 it was being revised by USDA for experimental application to experiment station projects funded by CSRS.

CSRS policies regarding the solicitation, review, and award of competitive research grants have been a focus of attention for alternative agriculture proponents and various professional organizations representing agricultural researchers' perspectives. This has been especially true for the $100 million per year NRI program. Although it receives less than 7% of USDA's total science and education budget, the NRI program is viewed as an important indicator of federal research policy because it encompasses the largest amount of agricultural research funding that can be federally directed toward particular social goals, topics, or scientific disciplines. CSRS program directors decide the research topics for competitive grants under broad, legislated NRI program areas. These topics can be highly specific, such as the mode of action of insect pathogens with potential for biological pest control, or much broader,

such as biological pest control in general. Federal program directors also decide how to interpret directions from Congress in considering proposals. CSRS determines what constitutes "multidisciplinary" in meeting congressional intent (for example, whether a plant pathologist and plant physiologist working together meet the criterion of "multidisciplinary"), and how the congressional intent of "mission-oriented" research is defined in practice. The operational definitions of "multidisciplinary" and "mission-linked" have been criticized as too narrow to advance alternative agriculture knowledge significantly (Bird and Hassebrook, 1992). Finally, CSRS program directors designate the processes by which grant proposals are reviewed and selected for funding. To date, the system has relied on traditional models of peer review under which disciplinary peers of proposers are asked to judge both the scientific merits of each proposal and its "relevance to long-range improvements in and sustainability of U.S. agriculture."

Does Research Policy Affect the Research Agenda?

Given these forces — congressional support for alternative agriculture research, the legislated opportunity for user input in setting research agendas, the substantial discretion of SAES and USDA in carrying out congressionally authorized and funded agricultural research, and attempts by USDA to assess how its research programs contribute to sustainability — there are few inherent, internal policy constraints on the evolution of publicly funded alternative agriculture research. In fact, there is ample opportunity for an alternative agriculture research agenda to flourish. However, this has not happened. In the remainder of this paper, I discuss the reasons for this apparent incongruity and suggest ways to address it through federal policy.

For one thing, it is easy to overestimate the strength and unanimity of congressional and USDA support for alternative agriculture research. Congress does not speak with one voice, and USDA and the research system try to please many congressional masters. Thus, agricultural researchers may receive mixed messages from research policymakers. It is especially critical to ask, however, whether researchers' agendas are or can be influenced by policy rhetoric.

Researchers' responsiveness to research policy direction

Agricultural research is the sum of the activities of agricultural researchers. To have an impact on agricultural research, therefore, the activities of the researchers must be affected. Unfortunately, the insularity, disciplinary conservatism, and decreasing rate of personnel turnover among agricultural researchers make it difficult to affect the activities of agricultural researchers through public policy.

An analysis of one land-grant university's agriculture faculty showed that its perspectives are closer to those of proponents of conventional agriculture than of alternative agriculture. In fact, some disciplines' faculties are more conventional in their outlook than are conventional agriculture groups (Beus and Dunlap, 1992). This conservatism relates to an insular culture of agricultural research, one that is still dominated by a homogeneous group consisting mostly of white males with farm backgrounds, organized around disciplinary departments and taking a reductionist approach to science (Busch and Lacy, 1983; Buttel, 1985). Research institutions cannot easily or quickly resolve any demographic imbalances in their current research staffs or faculties. The only way to change the profile is through preferential hiring of researchers with different backgrounds, interests, perspectives, and skills. However, with declining base funds for research and the resulting hiring freezes or slowdowns, this strategy can only be a long-term approach.

In the short run, we need to understand what motivates current researchers and ask how public policy does or might influence what topics they pursue and how they pursue them. The major incentives to which the typical agricultural researcher can be expected to respond are peer recognition and financial support. How much does agricultural research policy affect peer recognition and financial support?

The criteria for peer recognition in the agricultural sciences, as in science generally, are specific to the discipline. They rely upon intradisciplinary communication, often through refereed journals, and are supported by academic promotion and tenure processes. The importance of peer recognition slows or prevents the acceptance of an alternative agriculture research agenda because the associated reward system favors disciplinary over interdisciplinary research. It also favors more rapidly completed (and published) research on individual elements of agricultural, agroenvironmental, and food systems than research on the nature of those systems themselves. Furthermore, standard peer review processes place interdisciplinary and applied research proposals at a disadvantage in competitive grants processes because reviewers favor proposals that conform to their own disciplines' standards of quality (Porter and Rossini, 1985).

Despite this important influence, I do not believe that public policy should try to modify peer-based systems of professional reward. Because good, peer-recognized scientists easily move from one institution to another, an individual state or the federal agricultural research system could not, even if it wished to, unilaterally impose new criteria for professional rewards without the risk of losing peer-sanctioned scientific credibility. As Nipp (1993, p. 27) put it, "Changing the reward system is a problem that has no resolution because no individual piece of our system has the ability to step out and solve it." The public-private research and education system has recognized this problem and is wrestling with it on its own, for reasons that go well beyond the issue of agricultural research.

Public policy can, however, influence where, how, and how easily researchers obtain financial support for their work. A recent study at the University of Minnesota showed that faculty members and administrators have a wide range of opinions about how important the tenure system and disciplinary orthodoxy are in shaping the research agenda. However, they are unanimous that "funding plays a significant role in determining what scientists do and do not research," so that funding in essence drives the research process (Glassman, 1993). USDA, Congress (with input from the land-grant system), and some states explicitly allocate agricultural research funding among categories or topics. Also, the process for setting research priorities, both federally and in many states, provides for

research users' input and guidance. In principle, then, as users identify a need for alternative agriculture research, funds will be allocated in that direction, researchers at federal and state-funded institutions will shift their research agendas accordingly, and the sum of their activities will represent an alternative agriculture agenda. That this is not happening to any significant extent suggests a conflict between theory and practice.

The limited influence of federal funding policy

There are several reasons that federal policies on funding agricultural research have had only a minor effect on the agricultural research agenda. Federal funding represents a small and declining proportion of funds available to agricultural researchers at state agricultural experiment stations. User input has not been effective in guiding the allocation of funds, either to the SAESs or within USDA. Congressional intent attached to allocated funds has more often been expressed through gentle prodding than forceful direction, and there is no mechanism for insuring that USDA or university-based fund recipients are accountable in fulfilling federal funders' intentions.

Two trends have opposite but unequal effects on federal research funding at the SAES. One is the increasing share of CSRS-administered funds allocated by special and competitive grants. The other is the steady decline in the CSRS-administered share of total SAES funds, including formula funds and grant program funds, from 25% in 1957 to 14% in 1990 (Huffman and Evenson, 1993).

In deciding whether and how to use formula funds to influence the type or direction of research, the SAESs are not accountable to the federal government, although they are accountable to state and local groups. Thus, national priorities, including those specified by Congress, which appropriates Hatch and other formula funds, or by USDA, which administers those funds, may carry little or no weight compared with local interests. In contrast, the relative growth in federal funding categories that specify particular subjects corresponding to national priorities (through special and competitive grants) should increase the influence of federal funding on the research agendas of the SAESs.

On the other hand, because state nonmatching and private sector funds are an increasing share of total funding, federal influence is declining even though each federal dollar may, on average, carry more weight in influencing the system. The net decline in federal influence was confirmed by Meyer (1993, p. 1007), who reported that "professional leaders of the land grant universities surveyed in 1992 downplayed the importance of federal government leadership."

This limited federal influence persists despite efforts by users of agricultural research to guide priorities. The system of formal advisory groups has proved ineffective. Representative George Brown, a champion of the system that established the Joint Council and the Users Advisory Board, is among those who now believe the process "failed to produce the desired results" (Brown, 1994, p. 3). It appears reasonable to attribute this failure to the lack of incentives for either Congress or USDA and the land-grant system to follow the advice of the advisory groups. There is no mechanism to make recipients of the advice accountable for not heeding it. Lack of accountability by recipients of federal agricultural research funds is a system-wide problem. Congressional admonitions to USDA to establish or change priorities may have led to some uncomfortable congressional committee hearings, but the budget process does not seem to be affected by whether the Department demonstrates to Congress's satisfaction that it is responsive to congressional direction. In fact, apparent collusion in the allocation of funds to and within such programs as the NRI suggests more of a political "iron triangle" among Congress, USDA, and the SAESs than a hierarchical system under which the federal government even attempts to exert top-down influence on research priorities or agendas.

Some Proposals for Reforming Research Policy

The preceding sections have reviewed how agricultural research policy is made and why it has had only a limited effect on the direction of research. Although there is ample opportunity to redirect research toward an alternative agenda, progress has been slow, mainly because neither professional rewards nor financial incentives for such a shift are sufficiently strong. Since government policy is not the appropriate mechanism for revising professional standards or reward systems, reform must focus on the financial incentives that influence researchers. But since the federal budget deficit makes it highly unlikely there will be significant additional funding for new agricultural research priorities, proposals for policy reform will be most realistic if they address research funding procedures rather than the size of the "money pie" being allocated. Some potentially fruitful areas of reform along these lines include: tying a greater share of federal funds to specific research priorities; articulating priorities among goals and missions; making more effective use of user input in deciding research policy; and requiring greater accountability of research fund recipients. In the following sections, I discuss some mechanisms for achieving these goals for policy reform.

Means testing for formula fund payment limitations

Given expected constraints on the growth of total federal agricultural research funds, some critics of the USDA-SAES system have proposed transforming all or some formula funding into special research or competitive grants programs. This could, for example, fund a substantially larger SARE program, or make new competitive grants available for agroecological research. Opponents of such a move suggest that a reduction in formula funding would "cause an increase in wasteful project-seeking resources and impinge upon the capacity of the States to serve local clientele groups" (Huffman and Evenson, 1993, p. 255). It might even prevent researchers whose independent investigations of alternative agricultural systems are supported by formula funding from continuing to pursue a long-term research plan free from the constraints imposed by shorter term grants.

Furthermore, some states' agricultural research programs would be devastated without formula funds. On average, about

half of USDA funding and about one-third of all federal funding of agricultural research in the SAES system is distributed by formula, without effective federal influence on its use. However, the importance of formula funds varies substantially across states. Some SAESs rely on formula funds as the basis of their agricultural research program; others use them as a small but important supplement to more lucrative nonformula or nonfederal funds. Since the states that rely most on formula funding tend to be those in which small farms are heavily concentrated (Schweikhardt and Whims, 1993), eliminating or cutting the formula funding base across the board probably is politically infeasible, and could work against some alternative agriculturalists' goals.

A better alternative would be to place a cap on the formula funds going to each experiment station, with the cap going into effect only when the station received more than a specified share of its funding from sources other than federal formula funds. This would insure base formula funding for all SAESs and protect those that rely heavily on formula funds, but would release for other uses some formula funds that now go to institutions that compete effectively for other funding. In theory, the institutions that lose some formula funding would have the best chance to recoup it elsewhere. However, the funds recouped through special programs or competitive grants would address targeted priorities rather than being allocated at the discretion of the recipient institutions.

This idea is akin to proposals to target federal farm program support to particular types of farms. Its feasibility and desirability depend on two factors: how it would affect the geographic distribution of total federal research funding, and whether it might cause some SAESs to seek more grants outside the newly prioritized public agricultural research system. The latter would move some institutions even farther from the influence, however subtle, that federal funders can have in stimulating an alternative agriculture research agenda.

Priority setting as a condition for receiving public research funds

Suppose that Congress required USDA and that CSRS required the SAESs to announce publicly a ranked list of specific institutional research priorities before they could receive federal research funds by any funding mechanism. Researchers at federal and SAES institutions where research agendas have not been set clearly or openly would now have a precise target toward which to aim new research ideas. Although researchers are motivated by peer recognition and funding opportunities, most would, when all else is equal, also like to be acknowledged as contributors to institutional goals. For them, clear institutional goals would be a boon.

Equally important is that public announcement of priorities would allow the interested public to react to an explicit rather than to an assumed research agenda. At present, the public has little information to react to beyond public relations material. Assuming there is a vocal public that would support research priorities in tune with alternative agriculture and would object to research priorities seen as detracting from its potential, public reaction to announced priorities could support a grassroots shift toward more alternative agriculture research.

I am not proposing any federal direction, control, or authority over the priorities of federally funded agricultural research. The proposal would merely provide the missing incentive for institutions to identify research priorities systematically and to declare them publicly. Furthermore, no direct federal intervention would be necessary to shift priorities in a way the interested public prefers; the public would now have the necessary information to act on its own if it sees a shift as valuable.

Goals as the basis for public research decisionmaking

A possible supplement to the previous proposal is to mandate that federally funded research programs be categorized by the specific social goals toward which they are directed, rather than by broad subject matter or scientific discipline. This would require significant reform of the Current Research Information System (CRIS), the present way that federally funded research projects are summarized, categorized, updated, and reported. Reports on federally funded agricultural research are accessible to anyone who understands the complex CRIS system well enough to make an appropriately framed request. However, no periodic report is routinely prepared from the CRIS information and released for public examination.

Under CRIS, the principal investigator of each federally funded agricultural research project, whether conducted within a USDA agency, a state experiment station, or both, classifies it as falling within one of one hundred Research Program Areas (RPAs). Each RPA, in turn, falls under one of nine predetermined goals. For instance, CRIS Goal III is to "produce an adequate supply of farm and forest products at decreasing real production costs." It includes such RPAs as "Genetics and Breeding of Forest Trees", "Farm Business Management", and "Bees and Other Pollinating Insects." Although the present system does provide for some classification by goal, it is inadequate for assessing how federal funds contribute to research on the goals of greatest interest to the public, or to proponents of alternative agriculture. For example, if a project is classified within RPA 204, "Control of Insects, Mites, Slugs and Snails on Fruit and Vegetable Crops," under Goal II, "Protect forests, crops and livestock from insects, diseases, and other hazards," one cannot tell whether the project is directed toward increasing the efficiency of pesticide use or toward reducing reliance on pesticides to improve food safety. Also, the CRIS goals are so limited and the RPAs so outdated that they cannot readily accommodate a range of modern research topics, such as livestock housing to improve animal well-being, the implications of agricultural industrialization for agricultural sustainability, or the agroecological consequences of alternative farming systems.

I propose three specific revisions of CRIS for improved accountability on research goals. First, each year, all principal investigators would be requested to state, in their own 25 words or less, the primary social goal addressed by their projects. Second, they would classify their project according to a substantially revised set of CRIS goals. The revised, updated, and more relevant set of CRIS goals should be developed by USDA with input from the alternative agriculture community and other constituents of the agricultural research system to insure that the goals are

appropriate for current issues. Finally, the allocation of federal agricultural research funds would have to be reported according to (revised) CRIS goal categories to provide needed accountability to national priorities.

The benefits of these proposed actions would be twofold. First, requiring researchers to articulate their research program in terms that are meaningful to the public, besides those their scientific peers can understand, would be a small but possibly significant stimulus for researchers to shift their personal agendas toward public priorities. Second, it would create a more relevant basis for judging how well federal agricultural research programs meet Congress's intent regarding alternative agriculture and other socially motivated directions for agricultural research. Better information for alternative agriculturalists and public citizens to get involved in the public agricultural research process would be an important byproduct of these proposed policies.

Reporting relevant information for accountability

Another way that reporting on federally funded agricultural research could be made more relevant to alternative agriculture would be to require reporting on the results of administrative implementation of congressional intentions for more alternative agriculture research. For example, the manner in which USDA uses the concept of "multidisciplinary research" in making decisions about NRI competitive grant awards (at least 30% of which must, by law, be conducted by multidisciplinary teams) will determine whether the NRI increases researchers' inclination to seek interdisciplinary solutions to agricultural problems. At present, NRI Competitive Grants Program reporting includes CSRS program managers' estimates of the number of awarded projects that are "multidisciplinary," but it does not show what combinations of disciplines comprise the so-called multidisciplinary teams. Some people would not consider that a team consisting only of animal scientists (e.g., an animal geneticist and an animal nutritionist) or only of plant scientists (e.g., a plant pathologist and a plant physiologist) is as suitable in meeting alternative agriculture goals as one that includes an animal scientist, a plant scientist, and a social scientist. However, they would have no way of judging whether their criterion for multidisciplinary research was being met. The simple requirement of listing the disciplinary combinations deemed "multidisciplinary" under NRI awards would provide accountability in this important area.

Similarly, documentation could be required of what constitutes the systems investigated by federally funded research designated as "systems research," how farmers are involved in farm-level research, and what scales of farm operation are likely to be able to adopt projects' anticipated technological outputs. This would create additional bases for judging whether alternative agriculture models are being adopted. Such moves would supplement accountability through designation of social goals for projects and protocol-based assessments of projects' contributions to agricultural sustainability.

Public participation in research grant reviews

The current advisory committee structure has failed to influence public agricultural research agendas significantly, in part because committees' advice comes before research program planning and carries no incentives for following the advice. Therefore, outside advisers, including those concerned with alternative agriculture, ought to be more directly involved in research planning and implementation. One way to do this is to build public participation into the review and selection of competitive grants. This would supplement rather than substitute for scientific peer review.

There already is precedent for public participation in the review of federally funded research. The National Institutes of Health (NIH), one of the largest federal contractors for basic and applied research, uses a two-tiered grant review process. This process was instituted because clinical research (the medical equivalent of applied agricultural research) did not fare as well as basic research under standard peer review. The new process relies on a scientific peer review panel to identify proposals with highest scientific merit. This panel passes its recommendations on to a second review committee that judges how well the most scientifically meritorious proposals meet institutional goals and priorities (National Institutes of Health, 1992). Two-thirds of the second committee are scientists whose specialties are not necessarily those addressed by submitted proposals, and one-third are members of the public who have interests in federally funded medical research. According to the NIH, "the dual review system, which separates . . . scientific assessment . . . from policy decisions about scientific areas to be supported and the level of resources to be allocated, permits a more objective evaluation than would result from a single level of review [and] provides the responsible NIH officials with the best available advice about scientific as well as social values and needs" (National Institutes of Health, 1992, p. 4).

There is no reason that a similar two-tiered review system could not be used to differentiate scientific truth from social utility (Chubin, 1993) when awarding competitive grants for agricultural research. Such a system would foster alternative agriculture research by facilitating meaningful participation by farmers and alternative agriculture proponents in setting the research agenda. Some combination of external, scientific peer review of USDA's intramural research program plans and public review for relevance would also be useful in guiding USDA researchers and insuring the greatest opportunity for promoting alternative agriculture in ARS, ERS, and the Forest Service.

Limitless Opportunities and Practical Limitations

These proposals all would encourage greater responsiveness by a public agricultural research system that already possesses the flexibility and infrastructure for supporting alternative agriculture. The proposed actions could easily be accommodated within the congressional authorization and appropriations processes, and they complement other calls for reform of the agricultural research system.

The opportunity for greater mission-oriented direction of federally funded agricultural research, new bases for judging accountability of the agricultural research

system in addressing social goals, and involvement of the public in awarding grants and setting the research agenda also would apply to pesticide reform, socially responsible application of publicly funded biotechnology, and scale neutrality of publicly funded research and development. Furthermore, such moves are consistent with growing congressional calls for a post-Cold War redefinition of what constitutes science in the public interest. As Senator Mikulski (1994, p.221) has put it, the "new world order has profound repercussions for Federal science policy," among which are a "new paradigm . . . on how science is conducted and how it is organized," the need for choosing research priorities strategically, and providing greater accountability of federally funded scientists to the public, Congress, and the Executive Branch.

Despite these opportunities and their advantages, several factors limit how much these proposals can stimulate a shift toward alternative agriculture. One is that researchers are motivated by the availability of funding, but USDA controls less than half of the roughly $2.4 billion in total funds supporting the entire public agricultural research system (including in-house, SAES, and other extramural research). All federal funds constitute only about one-quarter of the total funds for agricultural research at SAESs (Huffman and Evenson, 1993). Thus, reforming federal research policy regarding allocation of funds and accountability will come up against the influences of other funding sources that provide most of the funding. Of particular importance over the long run is the growing proportion of private sector funds for public agricultural research institutions. To the extent that private funding provides counterincentives to federal direction, it limits the effectiveness of federal policy. This issue is especially critical for alternative agriculture because we can assume that the products of alternative agriculture research are likely to be public goods, unlike the products of privately funded research.

A second limitation arises because except for greater accountability about what constitutes "multidisciplinary" and "systems" research, these proposals mainly address the subject matter and goals of agricultural research rather than how research is conducted. Alternative agriculture relies on research that is conducted within a holistic framework and involves farmers and the community as partners. Greater openness in decisions about public agricultural research and in the identification, prioritization, and dissemination of institutions' agricultural research goals will invite more involvement by farmers and citizens. However, it will not necessarily make them partners in the actual experimentation. Having more agricultural research carried out by multidisciplinary teams will not guarantee that it will also be more holistic in scope and applicability. Furthermore, none of the proposed federal policy directions will affect the quality of research.

Finally, a strength of the proposals — that they are readily accommodated (even if not entirely welcomed) within the current policy and research systems — also is a weakness. These are evolutionary steps that merely would provide a more conducive and supportive environment for alternative agriculture research, but they would not greatly accelerate a paradigm shift. Those who contend that alternative agriculture requires an alternative research system must deal with issues that go well beyond the roles of USDA and the land-grant system and the limited influence of public policy.

Acknowledgment. The insightful comments and suggestions provided on an earlier draft of this paper by Nicole Ballenger, Elizabeth Bird, and Kathleen Merrigan are greatly appreciated.

References

1. Beus, C.E., and R.E. Dunlap. 1992. The alternative-conventional agriculture debate: Where do agricultural faculty stand? Rural Sociology 57:363-380.
2. Bird, G.W. 1993. Transitioning to an age of sustainable development. In Toward the 21st Century: A Multidimensional Transition of the State Agricultural Experiment Stations. ESCOP 93-1. Experiment Station Committee on Organization and Policy, and U.S. Dept. of Agric., Cooperative State Research Service, College Station, Texas.
3. Bird, E., and C. Hassebrook. 1992. Report card on USDA research policy. Center for Rural Affairs, Walthill, Nebraska.
4. Brown, G.E., Jr. 1994. Remarks before the NAS Board on Agriculture Committee on Land Grant Colleges of Agriculture at 130. Washington, D.C., and Irvine, California. January.
5. Busch, L., and W.B. Lacy. 1983. Science, Agriculture, and the Politics of Research. Westview Press, Boulder, Colorado.
6. Buttel, F.H. 1985. Public agricultural research and education policy and the development of resource-conserving agricultural systems. In Proposed 1985 Farm Bill Changes: Taking the Bias Out of Farm Policy. Institute for Alternative Agric., Greenbelt, Maryland. pp. 19-39.
7. Charles Valentine Riley Memorial Foundation. 1994. Science Communications and Enhanced Agricultural Policy. Proceedings of a Science Communications Round Table, November 16, 1993. Lanham, Maryland.
8. Chubin, D.E. 1993. Peer review, pork, and priorities in agricultural research. In R.D. Weaver (ed). U.S. Agricultural Research: Strategic Challenges and Options. Agric. Research Institute, Bethesda, Maryland. pp. 255-269.
9. Consortium for Sustainable Agriculture Research and Education. 1994. Consortium News, Vol. 1, (February). Center for Rural Affairs, Walthill, Nebraska.
10. Glassman, J. 1993. Shaping the research agenda: A faculty perspective. At the Crossroads 3(2):1-2, 7-8, Northern Tier Land Grant Accountability Project, St. Paul, Minnesota.
11. Hassebrook, C. 1989. Agricultural research as social planning: Setting agricultural research priorities to advance social goals. In Reform and Innovation of Science and Education: Planning for the 1990 Farm Bill. Committee print, Committee on Agric., Nutrition, and Forestry, U.S. Senate, December. U.S. Govt. Printing Office, Washington, D.C. pp. 207-213.
12. Hightower, J. 1973. Hard Tomatoes, Hard Times. Schenkman Publishing Co., Cambridge, Massachusetts.
13. Holt, D. 1989. Federal support of adaptive agricultural research and extension. In Reform and Innovation of Science and Education: Planning for the 1990 Farm Bill. Committee print, Committee on Agric., Nutrition, and Forestry, U.S. Senate, December. U.S. Govt. Printing Office, Washington, D.C. pp. 235-245.

14. Huffman, W.E., and R.E. Evenson. 1993. Science for Agriculture: A Long-Term Perspective. Iowa State Univ. Press, Ames.
15. Meyer, J.H. 1993. The stalemate in food and agricultural research, teaching, and extension. Science 260:881,1007.
16. Mikulski, B.A. 1994. Science in the national interest. Science 264:221-222.
17. National Institutes of Health. 1992. Orientation handbook for members of scientific review groups. Public Health Service, U.S. Dept. of Health and Human Services.
18. National Research Council. 1972. Report on the Committee on Research Advisory to the U.S. Department of Agriculture. National Academy of Sciences, Washington, D.C.
19. National Research Council. 1989. Investing in Research: A Proposal to Strengthen the Agricultural, Food, and Environmental System. National Academy Press, Washington, D.C.
20. Nipp, T. 1993. Challenges of agricultural policy for the new administration. In The Future of Agricultural Research and Extension: Policy Perspectives. Rural Policy Research Institute, Univ. of Missouri, Columbia.
21. Phillips, M.J. 1990. Status of the U.S. agricultural research system: Challenges for the 1990s. Proceedings of the Annual Meeting of the Agric. Research Institute: Strategic Management of Agricultural Research, October 17, Washington, D.C. pp. 14-21.
22. Porter, A.L., and F.A. Rossini. 1985. Peer review of interdisciplinary research proposals. Science, Technology, and Human Values 10(3):33-38.
23. Rockefeller Foundation. 1982. Science for Agriculture. New York, N.Y.
24. Rodale, R. 1989. Agricultural sustainability research needs and progress. In Reform and Innovation of Science and Education: Planning for the 1990 Farm Bill. Committee print, Committee on Agric., Nutrition, and Forestry, U.S. Senate, December. U.S. Govt. Printing Office, Washington, D.C. pp. 13-18.
25. Schweikhardt, D.B., and J.F. Whims. 1993. Trends and issues in agricultural research funding at the state agricultural experiment stations. In R.D. Weaver (ed). U.S. Agricultural Research: Strategic Challenges and Options. Agric. Research Institute, Bethesda, Maryland. pp. 89-112.

BOOK NOTICES

So Shall You Reap: Farming and Crops in Human Affairs. Otto T. Solbrig and Dorothy J. Solbrig. 1994. Island Press, Suite 300, 1718 Connecticut Ave., NW, Washington, DC 20009. $27.50, hardcover. xx+284 pp.

This book surveys a wide range of food production systems, from the earliest agriculture through the present. The emphasis is on both the biological side of agriculture and its interaction with political, social and economic institutions. Rather than trying to cover the range of agricultural systems comprehensively, which would be impossible in a book of this size, the authors present a small but varied sample of systems that they treat in more depth, such as agriculture in the Fertile Crescent, the medieval estate, and sugar cane plantations. Considerable attention is devoted to resource and environmental issues, the book concluding with a discussion of how these may constrain agriculture in the future.

Unnatural Selection: Technology, Politics, and Plant Evolution. Cary Fowler. 1994. Gordon and Breach. $50, hardcover; $20, paper. xxiv+317 pp.

Concern over the loss of biological diversity and the control of plant genetic resources is a subject of heated debate these days, making this book very timely. It covers both U.S. law governing property rights for plants and international initiatives in this area. These topics are preceded by a lengthy section giving historical background on plant explorations and seed saving. About one-fourth of the book consists of appendices that cover loss of genetic diversity, information sources, technical terminology, and relevant legal theories.

New Wallace Institute Report Outlines Green Support Programs

A new, environmentally-based approach to farm income support called a Green Support Program (GSP) would "generate public environmental benefits by providing direct monetary payments to voluntarily participating farmers, who, in return, take actions that enhance or protect environmental quality," concludes a new report published by the Wallace Institute. According to "Lean, Mean and Green...Farm Support Programs in a New Era," in addition to providing a more compelling rationale for public support for farmers, the GSP approach would also, unlike current programs, support farm income without distorting commodity supplies or prices, be more consistent with greater market orientation of agriculture, assist farmers in meeting the requirements of environmental regulations, and provide the opportunity for big savings in federal agricultural expenditures.

"Lean, Mean and Green," by Sarah Lynch and Katherine Smith, is available for $7.50 from the Henry A. Wallace Institute for Alternative Agriculture, 9200 Edmonston Rd., #117, Greenbelt, MD 20770; (301)441-8777.

Removing applied agricultural research from the academy

William Lockeretz

Abstract. *Applied agricultural research that is concerned with highly specific production methods and growing conditions differs in its purposes and social value from more "academic" kinds of research intended to advance knowledge in a more general and less immediately practical way. Nevertheless, it is conducted in an institutional setting established largely for the latter kind of research. Many people have suggested that the resulting conflicts could be reduced by introducing greater flexibility into the professional reward system for agricultural researchers. However, the mismatch may go too deep to be fixed this way. An alternative would be to remove highly applied research from the academic domain and treat it instead as a service to the university's outside constituencies. A service orientation is especially appropriate for publicly supported universities, which is where most such research is done.*

Key words: peer review, land-grant colleges, alternative agriculture

Increased interest in alternative agricultural systems has renewed the debate over a question that dates from the early days of agricultural research: Can research serve the practical needs of agriculture while reflecting the scholarly values of its academic home? The question could be raised about research dealing with any agricultural production system as it is actually practiced by an area's farmers. However, it is raised especially often regarding "alternative" agricultural systems: those intended to conserve resources, protect the environment, enhance the social and economic well-being of rural communities, and produce safer, more wholesome foods, especially through reduced use of chemicals and other manufactured inputs. Research on such systems is commonly said to differ from "conventional" research not only in what it studies, but also in the way it should be organized, who should do it, how it should be done, and who is supposed to benefit from it (Bezdicek and DePhelps, 1994). The process by which such work is done, not so much what it studies, is what raises a serious question about whether it can flourish in an academic setting. (Here I am using the term "academic setting" narrowly. Although the university as a whole is usually spoken of as an academic institution, it does many other things too; by the "academy" I mean only the parts engaged in scholarly research.)

It is commonly assumed that even more than for conventionally oriented research, research on alternative systems should be done by multidisciplinary teams, involve farmers and other groups besides professional researchers, and be done on working farms (Lockeretz and Anderson, 1993, Chap. 2). Also, since many alternative systems involve longer rotations, projects may need to run longer to cover several rotation cycles. Whether alternative agricultural research in practice has these characteristics is uncertain (Anderson and Lockeretz, 1992); nevertheless, in many people's thinking, the *what* of alternative agricultural research is linked to the *how*, making it "alternative" in both respects. (A recent issue of AJAA [Vol. 9, Nos. 1-2, 1994], was devoted to alternative research processes specifically intended for investigating alternative production systems.)

Many observers have noted that these characteristics of alternatively oriented research conflict with the standards by which academic research is judged (MacRae et al., 1989; Soule and Piper, 1992, pp. 66-68, 212-215). In this view, research that meets the alternative agriculture ideal might not be publishable in a narrowly focused disciplinary journal, the kind that traditionally has been regarded as most prestigious. Some members of a multidisciplinary team will find their names relegated to the wrong end of a long author list, which is commonly thought to condemn them to professional oblivion. Longer projects mean fewer papers per year, a prospect that is especially unappealing for junior researchers, for whom the dictate of "publish or perish" can be very compelling. Finally, work done elsewhere than on traditional research sites, or done in collaboration with farmers or other "outsiders," may be suspect in some traditionally oriented circles as not scientifically valid research, or not even as research at all.

Because the usual academic standards are perceived as discouraging such research, many people have advocated reforming the prevailing reward system. Suggestions include emphasizing the usefulness of a researcher's publications over mere numbers, and giving appropriate credit for publications intended for farmers and other nonacademic audiences. Some institutions already have deviated from the customary reward system, and further change seems likely if the political atmosphere inside and outside the university continues to support it.

Beyond question it would be desirable to introduce greater flexibility and diversity in how the academy judges research, so that alternative approaches can flourish. However, this may not be an adequate response. First, the issue applies to much more than research with an alternative orientation. Second, reforming the reward system may not do enough to resolve the incompatibilities between the social purpose of applied research and the demands of the academy.

William Lockeretz is Professor, School of Nutrition, Tufts University, Medford, MA 02155.

Consequently, I suggest that we "deacademize" entirely a substantial portion of agricultural research, that is, define it as a nonacademic activity (although it could remain in the university as its institutional home). Much applied agricultural research by nature is not an academic kind of activity, so that it would be better pursued outside an academic context even if the academic reward system were made flexible enough to accommodate it. The point applies even to a substantial amount of research that is fully compatible with the current reward system: work that gets done in the "right" way and that results in frequent publications in the "right" kind of journals. Much of the research I have in mind for "deacademizing" is being done by people who have fared well under the current system and are not challenging either the prevailing ways that research is done or the standards by which it is judged.

Even though such "nonalternative" applied agricultural research seems compatible with the academic reward system, there is a deeper issue that should be addressed: the mismatch between the goals of much agricultural research and the ethos of traditional academic scholarship. The mismatch arises for any research that studies the practices actually (or potentially) used by farmers in a specific area, where the intended beneficiaries are the area's farmers or other groups outside the university. Rather than patching together a reward system that tries to reconcile the goals of highly applied, practice-oriented research on one hand and the more "academic" kind on the other, perhaps we should acknowledge the mismatch and work toward an amicable separation. Each should be allowed to fulfill its respective goals without having to distort itself into something it never was supposed to be.

My main reason for calling for a clearer distinction and separation between more practice-oriented and more traditionally scientific kinds of research is to avoid the problem of research that sits vaguely between the two, intending to fulfill the goals of both, but actually fulfilling neither. A typical small-plot agronomic study of a production system might involve two treatment variables. It might run for perhaps three years, and be done at one or maybe two locations. Yet the phenomenon being studied is likely to depend on many environmental and management variables. Typically, the experiment will give just a hint of this complexity, enough to show that there is more going on than we know about, but not enough to let us know what it is (Lockeretz, 1993). We might learn, for example, that the treatment that gives the best result is different from year to year, but not know how or why, because three years of data were not enough. (Having inadequate data to deal with routine year-to-year variability is a problem even in thoroughly "conventional" research on continuous production of one crop; thus it is an example of why the pressure for frequent publications hurts not just studies of "alternative" systems with long rotations.) Similarly, an experimental treatment may perform significantly better than the standard or control treatment on one soil but not on another; again, two soils are not enough for us to learn why. Such studies, therefore, are too narrow to contribute to a general scientific understanding of the phenomenon.

On the other hand, neither do they provide much guidance for practitioners, because such experiments typically are done under conditions that are too unrealistic to be directly applicable to working farms: often the plots are too small, "confounding" effects like insect or weed pressures are controlled more completely than could be done on a working farm, and field operations are performed closer to the optimum time than a farmer could realistically achieve. Moreover, such research commonly measures just a few outcome variables, such as yield, but omits other factors that are important for whether a treatment will be appropriate and attractive for farmers, such as its labor requirements, production costs, or compatibility with other farm operations.

Academic Agricultural Research: Not the Only Valid Kind

How sharp is this conflict I claim exists between highly applied research and the traditional notion of "scholarly" or "academic" research? Does it really mean that the former would be better off outside the academic domain, even if the academy were to become more hospitable toward it? If so, what alternatives are available?

The root of the conflict arises from the most fundamental question of all: For whom is the research being done? The audience for traditional academic research — its main immediate "users" — consists of other researchers working on related questions. Therefore, the definition of a legitimate research question and the standards for evaluating research are set by one's disciplinary counterparts. The first goal of such research is to advance knowledge. It also may lead to practical benefits — academic research can be "applied" — but the path from research to benefits is indirect. The results of an individual piece of research first are made part of a cumulative body of knowledge. This enhanced knowledge in turn may result in a new product, technique, or other practical application, but an individual piece of academic research — even the kind considered "applied" — only rarely gets put directly into practice.

Therefore, research prized within the academy must have some value and significance even for people concerned with different growing conditions. This does not mean that if the study were done somewhere else it would have to get the identical results — agriculture doesn't work that way. But the research must at least be interesting to people elsewhere, conceptually even if not for the direct practical applicability of its results. This does not exclude a purely empirical study conducted under very specific conditions; detailed, highly site-specific data can be valuable both practically *and* scientifically. However, the results of such a study must contribute (eventually) to advancing our broader knowledge and understanding; that is, there must be some reason to fill that particular data gap (Lockeretz and Anderson, 1993, Chap. 4). That the study can help solve a problem under particular conditions may be an excellent reason to do it. However, that does not make it "academic" research as I have characterized it, unless one can legitimately argue that the results also will be of more general interest.

Another way that some agricultural research does not fit the usual notion of "academic" is that the latter is supposed to reflect a sophisticated scientific understanding that we expect to find only in

highly trained researchers working at the frontier of scientific knowledge. This is why it is considered so prestigious, an issue whose consequences I take up later. Also, it is supposed to be *original*. Demonstrating one's ability to do original scholarship is the characteristic feature of the Ph.D., the degree that most commonly marks the person considered qualified to do academic research (Storr, 1973, Chap. 6). This level of research is not supposed to include routine application of well worked-out techniques that simply are being applied to a different situation.

Much problem-oriented, location-specific research on production practices, whether "conventional" or "alternative," does not fit these criteria. It is not a question of whether such research is more or less valuable to society than the more "academic" kind. Doing academic-type research is not the only way that agricultural researchers can benefit society; conversely, some research that indisputably is academic does not benefit society at all. The point is that researchers who are not trying to achieve what "academic" researchers traditionally are supposed to achieve should not be indiscriminately lumped in that category, nor should they want to be.

Consider, for example, research on a cultivation technique that has been developed somewhere else, but that might offer effective nonchemical control of a serious weed in one's own region. If the research shows that the technique controls the weed better, without increasing production costs, erosion, and so forth, that is more than enough justification for having done it. But such research often will use essentially the same experimental design and data analysis methods as would have been used several decades ago. Also, the results will not be of much interest to someone working under conditions where we would not expect them to apply. What justifies this research is what it offers to farmers and the public, not scientists.

It would be inappropriate and unfair to judge such work by traditional academic standards: it differs in its goal, style, and beneficiaries. Thus we should take it out of the domain of academic scholarship and call it something more appropriate, such as "service." We also should reconsider what institutions and what kinds of people should do such research. Work of this kind already is being done outside the university. In fields other than agriculture, it is the domain of marketing consultants, consumer product testing organizations, private research and development firms, and so forth. Within agriculture, it is being done by groups of farmers on their own farms, by state agencies, and by nonacademic nonprofit organizations that either have their own experimental farms or use farmers' fields (Thompson and Thompson, 1990; Rosmann, 1994).

Agricultural research would benefit greatly if more such organizations got involved in highly site-specific, practice-oriented field research. Nevertheless, both for practical reasons, such as availability of facilities and supporting services, and for intellectual reasons, especially the opportunity to exchange ideas with people doing other kinds of research, much research of this kind now done in universities should remain there. However, the people who do it should be regarded as on a different career track from those who do research in the narrower academic sense. The reason is to free them from having to work in a setting dominated by the values of academic scholarship, when that is not what they are supposed to be doing. The customary question "What did they contribute to the *science* of agriculture?" is not appropriate. The more relevant question is "What did they contribute to *agriculture*?"

This would mean, for example, that lead authorship of a disciplinary publication would not be the only thing that counted. In fact, it probably would not count at all — a disciplinary research journal is not where we would usually expect such research to be published anyway. The "product" of such research is not a professional research publication — it is an improved agricultural system. A person working in this service mode, freed from expectations regarding academic publications, can address whatever questions most deserve to be studied, for however long it takes, with whatever collaborators are right for the task (whether they are from the same discipline, other disciplines, or no discipline).

Some researchers have been able to function in this mode on their own, if their particular departments happen to look favorably upon such work. Moreover, several colleges of agriculture have already established centers or institutes that are outside the academic departmental structure and that represent an institutional step toward the "deacademization" I have suggested. However, researchers in such units often have their primary appointments within a department, and therefore may be pulled in two incompatible directions. Also, disciplinary constraints are only part of the problem being addressed here: even interdisciplinary research faces many of the potential conflicts I discussed earlier between research regarded as academic in the traditional sense, and other kinds.

Consequently, my suggestion implies not only an institutional home other than an academic department — assuming the research is kept in the university — but also different job descriptions for the people doing it. Extension personnel are an example of agricultural professionals who do not hold academic research appointments — some do no research in any sense of the term — but who still have a university affiliation. A model for a university-affiliated position that does involve research, but of a nonacademic kind, is found in clinical medical research. Trials of a new drug, for example, are analogous to much applied agricultural research because they are intended not to advance scientific knowledge, but to study the efficacy and safety of a particular treatment, in anticipation of its use in the real world. Clinical researchers are needed in such work because of their skills in diagnosis, in monitoring patients for side effects, and so forth, not because they are expected to be creative or original in a scholarly sense. Such trials typically are conducted in teaching hospitals, an example of an institution whose primary activity is not academic research, but which still is university-affiliated. The clinicians engaged to do clinical trials are not regarded as academic researchers, and are not judged as such, although they clearly are doing a kind of research that society values. Although they will be included among the authors of research papers, their professional stature comes primarily from the services they provide using their clinical skills, not from their contributions as scholars.

Advantages and Disadvantages of Keeping Applied Agricultural Research "Academic"

Any proposal that suggests removing research from established academic structures and procedures raises the specter that we would be abandoning quality control, a function now served by academic peer review of publications and of researchers' job performance. However, peer review is neither the only way to maintain quality, nor a fully satisfactory way. For example, many nonscholarly magazines that cover science and other scholarly fields have well-deserved reputations for quality control. Also, the peer review system has not dealt with the much-deplored but still allowed practice of fragmenting one's work into "least publishable units" to rack up a large number of articles, to the detriment of meaningful scientific communication.

Researchers in the kind of position I am describing would still be subject to thorough, periodic evaluation. However, such an evaluation could legitimately be done by a wide range of people who have a good grasp of the area's agriculture, not just by people in the researcher's discipline. Compared with within-discipline peer reviewers who might be halfway across the continent, the former often will be better judges of whether the research addressed an important need and whether its results were interpreted appropriately. The land-grant university, too, might benefit from this change, because as a public institution, its political and financial support comes from external constituencies; the review process I am describing will help reduce the disparity between the type of work that gets rewarded in the academy and the type that rallies public support. However, even in highly applied research — the kind where one can make the strongest argument that what the public wants is what the university should do — I am not suggesting that professional advancement should be based on a popularity contest. Of course, meeting important needs is not enough: the research must also be valid technically. However, for research that uses familiar, well-established techniques, judging its technical correctness is much more straightforward than judging its value. Moreover, the option is always available of having appropriate disciplinary specialists review the work for technical validity. For example, some journals routinely have a statistician review every manuscript that involves statistics. However, this would only be a supplement to the more open-ended type of review I have described.

Another possible objection to sharpening the distinction between highly applied and more basic kinds of research is that it will intensify the competition between them for resources. However, I believe that distinguishing the two will reduce rather than intensify the competition. Academic infighting is much more feasible when one's opponents are close by. A collegial, supportive relationship among researchers with differing goals and values is not automatically achieved just by putting them together. It would be in the interest of both camps for each to be allocated a designated share of funds, positions, and facilities, instead of being left to fight it out internally, with the risk that one or the other will lose out entirely. In principle — I say this with the full understanding that it will sound hopelessly naive — such an allocation could be made by a "higher authority" who appreciated the value of both, and who sought an appropriate balance that best served the interests of the university as a whole.

Finally, a greater institutional separation between more applied and more basic research would, at first glance, interfere with fruitful intellectual exchange (which ideally should go in both directions). To this legitimate concern I offer two counterarguments: 1) being in the same unit does not guarantee fruitful intellectual exchange; 2) being in different units does not necessarily prevent it. We often hear criticisms of the inadequate interchange between agricultural scientists at the more basic and more applied ends of the spectrum, even when they are in the same department. The problem is not one of institutional structure. Rather, it is one of attitude, namely, a lack of interest in what one's opposite numbers are doing, not a lack of mechanisms by which one could learn. Other fields present a striking contrast. In medicine, for example, modern techniques like computerized axial tomography and magnetic resonance imaging first became theoretical possibilities because of advances in physics; instruments embodying these possibilities were developed by instrumentation specialists, systems engineers, and so forth; these instruments were turned into powerful and practical diagnostic tools by clinical researchers; now they are in common use in the real world of doctors and hospitals. Both intellectually and institutionally, physicists, engineers, clinical researchers and practicing doctors are much further apart than are their corresponding numbers in agriculture: basic and applied agricultural researchers, extension workers, and farmers. Nevertheless, they somehow bridged the gap. Is there a lesson here for agriculture?

Legitimizing Research as a Service versus Research as Scholarship

Some people would find it very exciting to be free to participate in projects that are strongly oriented to the world of real farming and that let them work with a wide range of collaborators, from both within the academy and the world outside. However, this choice often will subject them to prejudices that favor work considered "scholarly" or "academic." How, then, could we get anybody to do it? One solution would be to give them different job descriptions and titles from those of faculty scientists, so that they would not have to compete against others who are pursuing a different goal under standards that preferentially reward that goal.

This notion can be applied to specific projects, to entire categories of agricultural research, and even to entire institutions. For example, several private nonprofit research institutions with no academic affiliation have been established in recent years, generally to work on alternative production systems. Similarly, the Soil Conservation Service is a nonacademic institution that does research similar to some kinds that also are done at universities. (The Agricultural Research Service, by contrast, is not a good example; although it, too, is not an academic institution, it is quasi-academic in the expectations it places on its scientists.)

Research that can properly be put in the "nonacademic" category does not involve the frontiers of scientific understanding or techniques, but instead is done because someone "out there" will benefit from it. That is, it might help solve a problem that has recently emerged, or determine whether an innovation developed elsewhere is appropriate under local conditions. Such a study could be regarded as a service that the university provides to outside constituencies, more like extension programs, for example. On-farm research and demonstration projects, which often involve collaborations between farmers and the extension service or experiment station, already provide an example of work that does not fit the traditional notion of academic research but is done by people based in the university.

Forgoing the Prestige of the Academy: Not the Worst Possible Fate

Admittedly, if research is to be more a service and less an academic activity, this would require parts of agricultural science to forgo some of the status they gained when they became less practice-oriented and more academic. When they underwent that change, they largely adopted the values and standards of the older disciplines, those that flourished at the early research universities that were the first home of U.S. science in the 19th century. Those universities were, and remain, an elite group, and their ideals of "pure" research set a tone to which many other institutions and fields aspired.

But agricultural research gained the prestige associated with the academy at a cost: the possible conflict between serving the world of scholarship and serving the world of agriculture. The research universities whose style the agricultural sciences later emulated had no place for agriculture: they did only "pure" research. In such research there is no "outside" world that is supposed to benefit, at least not in a direct, predictable way. Rather, the researcher works on behalf of people doing similar work, who also are one's only judges. This is not true for agricultural research, which is why agriculture, like medicine, engineering, and many other professions and applied sciences, at first was not fully accepted as an academic field (Ben-David, 1971).

By now, of course, both the character of agricultural research and its stature within academia have changed drastically. Several developments were involved. First, the research universities themselves began to encompass more varied fields of study, including the "applied" sciences. Second, new kinds of universities with different ideals emerged, such as the land-grant universities, most of which originated as colleges of agriculture rather than research universities. Third, although agricultural science at first lagged far behind the "pure" sciences in its scientific sophistication, some branches have closed the gap, although in part this meant ignoring the distinctively human and cultural aspects of agriculture. Finally, all scientific disciplines were powerfully influenced by the dramatic increase in federal funding after World War II, which gave much greater importance to disciplinary, peer-reviewed publications (Kaplan, 1964).

Current debates over the purpose and goals of agricultural research should make us think very seriously about a fundamental question: Was acquiring its status as a legitimate branch of the academy worth it? For some areas of agricultural research — those closer in style to the older, "purer" sciences — no tradeoffs were required; many fields of agricultural research clearly have gained from becoming more integrated into the larger scientific community, a development that should be carried even further (Lockeretz, 1994). For other fields, however, becoming part of the academy meant becoming more isolated from their roots in the real world of farms and farmers, the result of adopting professional norms that at least in style — although not necessarily in intellectual content — made them more "scholarly" and "academic."

One result has been the obstacles to certain valuable kinds of research, as I discussed earlier: multidisciplinary research, research done on farmers' fields, and so forth. The task now is to find ways for such work to flourish, which does not necessarily mean letting it flourish within the academic domain. Being able to do it in the best possible way — sometimes, being able to do it at all — is more important than being able to call it by a particular label, however prestigious that label may be.

In thinking about changes in the profession that might bring this about, we should not assume that an ill-fitting academic value system — reflected, for example, in the "publish or perish" mentality — was imposed on agricultural research from outside. The field works that way because its members want it to; researchers can bemoan all they want the distorting consequences of the academic reward system, but no one forced the profession to adopt it. Being included among the elite ranks of the academy apparently was a compelling attraction.

But a profession that has chosen to "academize" itself also can choose to reverse that change. Those who believe that academic research deserves its prestige and who value it highly might find it hard to accept this change. But to a degree, prestige within academic circles matters only to the extent you think it matters. This applies especially strongly to fields funded by more "mission-oriented" agencies, as opposed to peer-reviewed competitive grants awarded mainly according to the scientific community's own criteria. With the former, the benefits that the research offers to the outside world no doubt count at least as much as how highly other academics rate its intellectual caliber. However, to be fair in laying claim to such funding, one must candidly acknowledge that one's work is a kind of public service, and not also try to appropriate the prestige surrounding the word "academic." Otherwise, one must be willing to compete with more academic or "basic" kinds of research on purely scientific criteria; realistically, this means being prepared to lose, because "applied" or "adaptive" agricultural research does not have the scientific glamour of more "basic" research (Gardner, 1990).

In striving for the "look and feel" of fields with a very different purpose, agricultural researchers may have been their own worst enemies. They cannot blame it all on university administrators, for example. Today, universities do many things that have little in common with the traditional academy, where intellectual advancement was prized above all else. Universities run hospitals, collaborate in commercial ventures, and field football teams.

The modern university is much more multifaceted than the early research university. Yet when it is time to evaluate a faculty member's contribution, the standards are mainly the narrower ones of the older institutions, largely because the profession wants it that way. Although it once may have been desirable for agricultural research to adapt to other fields' standards, today's university is more accommodating. Agricultural researchers could remain in the university as their institutional home but still say: "Ours is not a scholarly activity. We do what we do because people out there will benefit from it. The ideals of traditional scholarship do not fit us. Let the pure sciences continue to function by those ideals, but we are not part of that culture."

There should be no shame in saying that the value of one's work lies in how it benefits the outside world, not in how intellectually brilliant it is. "Applied" and "practical" should not be terms of opprobrium in agricultural research. The analogous distinction between practice-oriented and more academic kinds of activities creates no problem of prestige in many other fields, provided one does not only count prestige within disciplinary circles. The world outside the narrow circles of traditional scholarship clearly recognizes that success in practice-oriented fields requires a large measure of talent, training, and skill, although not necessarily the same kinds that make for success in traditional scholarship.

Thus a good medical school will be sure to have not just good physiologists, but also high-caliber clinicians. A prestigious department of political science often will have not just political theorists, but also a former governor or mayor. A good music department must include not just musicologists, but also an "applied music" division with accomplished performers and teachers of performance. These people may not be scholars, yet the modern university has a place for them — often they are the university's superstars — because they are appreciated for what they are, not by the standards of physiologists, political theorists or musicologists. After all, whom would we prefer to have performing a delicate operation on us: the person who conceived the operation or a surgeon who has done it successfully hundreds of times? From whom would we prefer to learn what it's like to run a political campaign: someone who has analyzed 19th century elections or someone who recently was elected governor? Whose violin recital would we prefer to hear: an expert on historical performance styles or a good violinist?

So, too, the university should have a place for people skilled in the kinds of studies that will make agriculture better in a particular area, in the hands of real people, such as farmers. Such a study may not add to cumulative understanding of agricultural principles, and to carry it out may not require advanced research techniques that qualify as "scholarly" activity: routine techniques that have long been used to answer similar questions may suffice. But such work requires people who have enough of a feel for agriculture to choose their research questions wisely, to understand the implications of their results, and to interpret their work for its intended beneficiaries. These people also must consider that making agriculture better is a sufficient reward, no matter how their work is rated by fields that have a different purpose. Finally, their institutions must accept this outlook; for the land-grant colleges, this acceptance amounts to reaffirming their historical mandate.

I believe there is a serious incompatibility between the social purpose of much of agricultural research and the prevailing values of the academy. This incompatibility may be too deep to be fixed by patching the prevailing system. Reform-minded agricultural researchers may be missing the point when they berate the academy for a "one size fits all" approach that imposes inappropriate standards on them; nor should they distort their work just to get it accepted according to those standards. Rather, they should define their work as fundamentally different from what research universities once were set up to do. This will free them to concentrate instead on what the public pays them to do, which is to improve our agricultural system.

Acknowledgment. I am grateful for the many thoughtful comments that Colette DePhelps, Peter J. Goldmark, and G.W. Stevenson made on a draft of this paper.

References

1. Anderson, M.D., and W. Lockeretz. 1992. Sustainable agriculture research in the ideal and in the field. J. Soil and Water Conservation 47:100-104.
2. Ben-David, J. 1971. The Scientist's Role in Society: A Comparative Study. Prentice-Hall, Englewood Cliffs, New Jersey.
3. Bezdicek, D.F., and C. DePhelps. 1994. Innovative approaches for integrated research and educational programs. Amer. J. Alternative Agric. 9:3-8.
4. Gardner, J.C. 1990. Responding to farmers' needs: An evolving land grant perspective. Amer. J. Alternative Agric. 5:170-173.
5. Kaplan, N. 1964. Sociology of science. In R.E.L. Faris (ed). Handbook of Modern Sociology. Rand McNally & Co., Chicago, Illinois. pp. 852-881.
6. Lockeretz, W. 1993. Replicability in agricultural field experiments. Amer. J. Alternative Agric. 8:50,93.
7. Lockeretz, W. 1994. What non-land-grant researchers can contribute to agricultural sustainability. Amer. J. Alternative Agric. 9:28-33.
8. Lockeretz, W., and M.D. Anderson. 1993. Agricultural Research Alternatives. Univ. of Nebraska Press, Lincoln.
9. MacRae, R.J., S.B. Hill, J. Henning, and G.R. Mehuys. 1989. Agricultural science and sustainable agriculture: A review of the existing scientific barriers to sustainable food production and potential solutions. Biological Agric. and Horticulture 6:173-219.
10. Rosmann, R.L. 1994. Farmer initiated on-farm research. Amer. J. Alternative Agric. 9:34-37.
11. Soule, J.D., and J.K. Piper. 1992. Farming in Nature's Image. Island Press, Washington, D.C.
12. Storr, R.J. 1973. The Beginning of the Future. A Historical Approach to Graduate Education in the Arts and Sciences. McGraw-Hill Book Co., New York, N.Y.
13. Thompson, R., and S. Thompson. 1990. The on-farm research program of Practical Farmers of Iowa. Amer. J. Alternative Agric. 5:163-167.

The relative sustainability of alternative, conventional, and reduced-till farming systems

James D. Smolik, Thomas L. Dobbs, and Diane H. Rickerl

Abstract. *We compared the agronomic, economic, and ecological performance of alternative (organic), conventional, and reduced-till farming systems over a 7-year period. We evaluated the sustainability of the various systems regarding several concerns, including soil erosion, pollution potential, whole-farm productivity, energy use, environmental stress, economic performance, and farm size. The alternative systems relied primarily on forage legumes (alfalfa or clover) as substitutes for the pesticides and commercial fertilizers used in the other systems.*

Two studies were established in northeastern South Dakota in 1985. Study I emphasized row crops, Study II small grains. The alternative system in Study I, which included alfalfa hay in the rotation, was the most productive, both agronomically and economically. In Study II, the alternative system included a green manure crop (clover) in the 4-year rotation and had the lowest agronomic production; however, its economic performance was similar to the conventional system's. Year-to-year variability in production was lowest in the alternative systems. The alternative systems in both studies were the most energy-efficient, and the reduced-till systems the least. Judged by the distribution of nitrate-N in the soil profile, the potential for groundwater pollution was higher in the conventional and reduced-till systems in Study I than in the alternative system.

The alternative systems in both studies depended less on government payments for their profitability. Results in Study I also showed that more widespread adoption of alternative systems would tend to halt or slow the trend of ever-increasing farm size. These studies suggest that alternative systems are more sustainable in this agro-climatic area.

Key words: organic farming, energy use, whole-farm economics, whole-farm productivity, farm size

Introduction

Sustainable agriculture has been a topic of considerable debate and discussion in recent years. The term "sustainable" implies maintaining long-term productivity without degrading the resource base on which agriculture depends. Concerns about the sustainability of our current farming systems arise from several considerations, including soil erosion, pollution of ground and surface waters by agricultural activities, excessive reliance on nonrenewable energy sources (fossil fuels), environmental stresses, and economic stresses, including the declining number of farmers and their continued dependence on federal subsidies. Through the long-term multidisciplinary studies reported here, we evaluated the performance of alternative, conventional, and reduced-till farming systems regarding these concerns.

The Farming Systems project at South Dakota State University was begun in 1984 at the request of crop producers. The initial phase was on-farm studies designed to compare the long-term productivity of alternative (organic) and conventional farming systems. Data collection started in 1984 in several farmers' fields near Madison, South Dakota. Although on-farm components of the project have continued, questions from both farmers and researchers prompted us to expand the research in 1985 to include experiment station trials.

The objective of the experiment station trials conducted at the Northeast Research Station near Watertown, South Dakota was to obtain a more holistic understanding of the various elements of a farming system, including: crop yields; whole-farm economic performance; whole-farm productivity of the systems; influence of farming systems on soil nutrient relationships, soil temperature, soil water content, bulk density, residue cover, and snow catch; effect of systems on populations of nematodes, earthworms, arthropods, weeds, fungi, and bacteria; and mycorrhizal associations and soil fungistatic properties. Also, we wished to estimate the relative sustainability of the various systems. Results summarized in this article are primarily concerned with processes that differed among systems, and that appeared to have the most influence on the sustainability of the systems regarding the previously listed concerns. A more detailed report of results in these studies has been published as a bulletin (Smolik et al., 1993).

A review by Stanhill (1990) comparing the productivity of organic and conventional systems covered a wide range of environments, including the eastern U.S., U.S. Corn Belt, Germany, Australia, England, Israel, Sweden, and Switzerland. Some yields in organic systems were higher, and on average were within 10% of

Contribution No. 2789, South Dakota Agricultural Experiment Station

James D. Smolik is Professor and Diane H. Rickerl is Associate Professor, Plant Science Department, and Thomas L. Dobbs is Professor, Economics Department, South Dakota State University, Brookings, South Dakota 57007.

yields obtained in conventional systems. There is little current information based on long-term studies concerning the agronomic and economic performance of alternative (organic) farming systems in the North Central Region. In Nebraska, alternative systems may perform better than conventional systems under drought stress (Sahs and Lesoing, 1985; Helmers et al., 1986). Our transition stage research in South Dakota (Smolik and Dobbs, 1991), which involved five years of trials, showed that alternative systems potentially are competitive with more conventional systems in mixed row crop-small grain regions. We also have reported the effects of farming systems on mycorrhizae (Rickerl and Smolik, 1989a; Ananth, 1992), frost depth (Rickerl and Smolik, 1989b), soil temperature, bulk density, moisture, surface residues (Rickerl and Smolik, 1990), and weed ecology (Rickerl et al., 1993).

Agronomic and economic analyses have also been conducted for an actual operating "alternative" farm and an operating "conventional" farm in east-central South Dakota (Dobbs et al., 1991b). Because corn and soybeans dominate the cropping system of the conventional farm, that farm was more profitable on average than the alternative farm from 1985 to 1989. The federal farm program during the late 1980s played a significant role in that comparative profitability.

Recently completed case studies in other parts of South Dakota show a conventional farm to be more profitable in a "typical" year in the late 1980s than a low-chemical input farm in the south-central corn-soybean area. However, there was little difference in profitability between conventional and organic systems in the northern and western wheat growing areas (Dobbs et al., 1991a; 1992). In fact, when organic premiums were included in the wheat growing areas, the organic farms were slightly more profitable than their conventional counterparts.

Economic evidence from a few other studies also has begun to emerge. In a study covering nine different resource areas of the U.S., Ikerd et al. (1993) found opportunities for increased short-term profits with reduced-chemical systems compared with conventional systems. Chase and Duffy (1991) compared long-term profitability in a northeast Iowa study. They found a reduced-chemical system consisting of corn-oats-alfalfa to be as profitable as a conventional continuous corn system, but much less profitable than a conventional corn-soybean system. In Ohio, whole-farm profits of organic farms were greater than conventional farms, even though the organic farms had less cropland on average; however, their greater profitability was largely due to organic price premiums (Batte, 1992).

Our studies in South Dakota and a recently completed study in Kansas (Diebel et al., 1993) tend to show that alternative farming systems are more competitive in areas dominated by small grain or in transition areas between the Corn Belt and small grain areas than they are in the Corn Belt. A conventional system in northeast Kansas was compared with four different alternative systems that had forage or green manure legumes as part of their rotations. Two of the alternative systems were more profitable than the conventional system and two were less profitable.

Materials and Methods

We began two studies in 1985 at the Northeast Station. Previous crops in the study sites were reported in Smolik and Dobbs (1991). Study I emphasized row crops in three systems: ALT (no commercial fertilizer or pesticides and no moldboard plowing), a 4-year rotation of oats (*Avena sativa)* seeded with alfalfa (*Medicago sativa*)/alfalfa/soybeans (*Glycine max*)/corn (*Zea mays*); CONV (conventional tillage), a 3-year rotation of corn/soybeans/spring wheat (*Triticum aestivum*); and R-T (ridge till), a 3-year rotation of corn/soybeans/spring wheat. The ALT system in Study I was patterned after alternative crop-livestock systems in the on-farm studies near Madison, South Dakota; feedlot manure was applied to the oats-alfalfa plots each fall.

Study II emphasized small grains and included three systems: ALT (no commercial fertilizer or pesticides and no moldboard plowing), a 4-year rotation of oats seeded with sweet clover (*Melilotus officinalis*) and red clover (*Trifolium pratense*)/clover (green manure)/soybeans/spring wheat; CONV (conventional tillage), a 3-year rotation of soybeans/spring wheat/barley (*Hordeum vulgare*); and M-T (minimum till), a 3-year rotation of soybeans/spring wheat/barley. All systems in Study II were assumed to be cash grain operations. Study II was included because small grains traditionally have been important in the crop rotations in northeastern South Dakota, although row crops have become more prominent in recent years. Also, because moisture often limits crop production in South Dakota, the systems in Study II were designed to require less water than the systems in Study I, which included more full-season row crops and alfalfa hay. Overall, crops harvested in these studies represented the dominant crops produced in northeastern South Dakota and in much of the Northern Plains.

Soil type in the study areas was predominately Brookings silty clay loam, 0-2% slope (fine-silty, mixed Pachic Udic Haploboroll). The conventional and reduced-till systems received recommended rates of fertilizer and herbicides. We based fertilizer applications on soil tests, and scouted as an aid in deciding appropriate herbicide treatments. A moldboard plow was used only in the conventional systems following small grain harvest. Individual plots were approximately 3000 ft^2 in Study I and 2000 ft^2 in Study II. To minimize border effects we obtained yield and other data from the center area of each plot. Systems were replicated four times and arranged in randomized complete block designs with each crop grown each year. Field-scale equipment was used in planting, tilling, and most harvesting operations. Small grain yields were measured by harvesting an eight-foot wide swath from the center of each plot. To measure row crop yields, we harvested four soybean rows and two corn rows from the center of each plot. Forage yields were measured by mechanically harvesting a $3' \times 30'$ swath or, when a mechanical harvester was not available, by hand clipping a $3' \times 3'$ area.

Economic results are based on analysis of representative whole farms. We assumed that the representative farms had 540 tillable acres (about average for the area at the time the study began) and that they were in the federal farm program each year. Therefore, we took account of the required set-aside acres each year. We included both market prices and government deficiency payments in calculating the gross returns. Possible organic premiums for products of the alternative systems were not included in the calculations reported here, though they were considered in earlier analyses (Smolik and Dobbs, 1991). Crop prices, government pay-

ments, and set-aside requirements were updated each year. Input prices were updated periodically, as appropriate. We left the basic land charge constant, however, so that changing land values would not affect the comparisons of net returns over time.

The "typical" crop production practices used in the various systems are listed in Tables 1 and 2. Phosphorus (P) fertilizer and

Table 1. Typical crop production practices in Study I (1986-1992).[1]

Alternative	
Oats-alfalfa:	Disk w/harrow, packer behind drill, apply manure in fall (2.5 ton/A, dry wt.)
Alfalfa:	3 cuttings, fall chisel plow and field cultivate.
Soybeans:	Spring tooth harrow, field cultivate w/harrow, plant, rotary hoe twice, cultivate twice.
Corn:	Spring tooth harrow, field cultivate w/harrow, plant, rotary hoe twice, cultivate twice, fall chisel plow (w/sweeps).
Conventional	
Corn:	Field cultivate w/harrow, plant, band alachlor at 1.05 lb, apply 64 lb N, 4 lb P_2O_5, cultivate twice, fall disk.
Soybeans:	Apply 0.75-1 lb trifluralin, disk twice and harrow, plant, cultivate twice.
Spring wheat:	Field cultivate w/harrow, drill, apply 72 lb N, 7 lb P_2O_5, spray 0.75 lb diclofop plus 0.25 lb bromoxynil, or 0.25 lb MCPA, fall moldboard plow.
Ridge till	
Corn:	Ridge plant, band alachlor at 1.05 lb, apply 70 lb N, 4 lb P_2O_5, ridge cultivate twice, spray with 0.25 lb dicamba or 0.25 lb bromoxynil, shred stalks.
Soybeans:	Apply 0.35 lb paraquat, ridge plant, band alachlor at 1.05 lb, cultivate twice, spray with 0.38 lb acifluorfen, or 0.19-0.28 lb sethoxydim or 0.06 lb imazethapyr and 0.004 lb trifensulfuron, or 0.23 lb lactofen.
Spring wheat:	Field cultivate, hoe drill, apply 83 lb N, 7 lb P_2O_5, spray with 0.75 lb diclofop plus 0.25 lb bromoxynil or 0.25 lb MCPA, fall spray 0.75 lb glyphosate, fall chisel plow (w/sweeps).

[1] The herbicides applied over the 7-year period varied from year to year, and products listed include all materials applied from 1986 to 1992. Rates listed are a.i./A. Fertilizer rates (lb/A) are the averages for the 7-year period. Average seeding rates were: corn 18,900 seeds/A; soybeans 180,000 seeds/A; spring wheat 71 lb/A; oats 57 lb/A; alfalfa 9.5 lb/A.

Table 2. Typical crop production practices in Study II (1986-1992).[1]

Alternative	
Oats/clover:	Field cultivate w/harrow, packer behind drill.
Clover:	Mow, chisel plow (w/sweeps), field cultivate.
Soybeans:	Spring tooth harrow, field cultivate w/harrow, plant, rotary hoe twice, cultivate twice.
Spring wheat:	Field cultivate w/harrow, drill, rotary hoe once, fall chisel plow (w/sweeps).
Conventional	
Soybeans:	Apply 0.75-1.0 lb trifluralin, disk twice and harrow, plant, cultivate twice.
Spring wheat:	Field cultivate w/harrow, drill, apply 62 lb N, 7 lb P_2O_5, spray with 0.75 lb diclofop plus 0.25 lb bromoxynil, or 0.25 lb MCPA, or 0.25 lb bromoxynil, fall moldboard plow.
Barley:	Field cultivate w/harrow, drill, apply 21 lb N, 7 lb P_2O_5, spray 0.25 lb MCPA, 0.25 lb bromoxynil, or 0.75 lb diclofop, fall moldboard plow.
Minimum till	
Soybeans:	Plant, pre-emerge spray 3 lb alachlor or band 1.05 lb alachlor, post-emerge spray with 0.28 lb sethoxydim, or 0.38 lb acifluorfen, or 0.06 lb imazethapyr and 0.004 lb trifensulfuron, or 0.23 lb lactofen, fall spray 0.75 lb glyphosate, cultivate twice.
Spring wheat:	Spring tooth harrow, hoe drill, apply 82 lb N, 7 lb P_2O_5, spray 0.75 lb diclofop plus 0.25 lb bromoxynil or 0.25 lb MCPA, fall spray 0.75 lb glyphosate, fall chisel plow (w/sweeps).
Barley:	Field cultivate, hoe drill, apply 52 lb N, 7 lb P_2O_5, spray 0.75 lb diclofop plus 0.25 lb MCPA, or 0.25 lb bromoxynil plus 0.25 lb MCPA, or 0.25 lb MCPA, fall spray glyphosate 0.75 lb, fall chisel plow (w/sweeps).

[1] Herbicides applied varied from year to year, and products listed include all materials used from 1986 to 1992. Rates listed are a.i./A. Fertilizer rates (lb/A) are the averages for the 7-year period. Average seeding rates were: soybeans 180,000 seeds/A; spring wheat 71 lb/A; oats 57 lb/A; barley 58 lb/A, sweet clover 5 lb/A; red clover 4 lb/A.

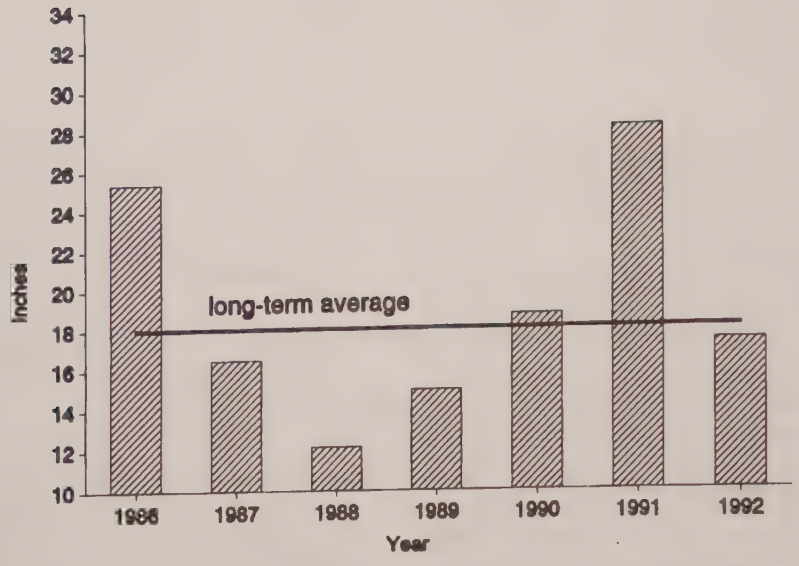


Figure 1. Growing season precipitation (April-October) at Northeast Research Station , 1986-1992.

banded herbicides were applied at planting in the conventional and reduced-till systems. P fertilizer was applied only in 1988 and 1989. Nitrogen (N) fertilizer was applied each year two to three weeks post-plant. Most South Dakota soils are naturally high in plant-available potassium (K), and no K fertilizer was applied. Herbicide inputs in the conventional and reduced-till systems varied from year to year, particularly in the reduced-till systems. Most crops in the conventional systems received only one herbicide application, whereas crops in the reduced-till systems required two or three applications. Broad-spectrum herbicides (e.g., glyphosate) were applied in the reduced-till systems only in the final two years (1991 and 1992). All row crops were planted in 36-inch rows, and small grains in 7-inch rows. The spring tooth harrow was used at early preplant in the alternative corn and soybeans to stimulate early weed seed germination before the final preplant tillage operation. More detailed lists of practices are given elsewhere (Rickerl and Smolik, 1990; Smolik and Dobbs, 1991; Smolik et al., 1993).

Results and Discussion

Because these studies compared different farming systems, crop yields were influenced by several interacting factors that differed among systems, such as tillage, sources and rates of nutrients applied, herbicides, and preceding crop in the rotation. The major influences on crop yields in South Dakota (growing season precipitation, temperature, growing season length, topography, and soil type) were similar for all systems. Growing season precipitation (April-October) was above the long-term average in three years and below in four years (Fig. 1); 1988 was the fifth driest year and 1991 was the wettest year in the 37-year history of the Northeast Station. Temperatures in June, July, and August of 1992 were the second lowest on record in South Dakota. Over the last seven years of the studies (1986-1992), the average growing season precipitation (18.99 inches) was 1 inch above the long-term average.

Agronomic relationships

Yields. Crop yields for the establishment year (1985) were reported in Smolik and Dobbs (1991). Corn yield was significantly higher in the CONV and R-T systems than in ALT, except in the 1988 drought year and the cool 1992 season. Soybean yield in the earlier years of the studies generally was not different between systems; however, in the last two years soybean yield was significantly lower in the R-T and M-T systems than in CONV and ALT. Spring wheat yield in both studies was closely related to growing season precipitation, except in the very wet 1991 season, when an epidemic of head scab (caused by *Fusarium graminearum*) severely reduced the yield in all systems. In Study I, spring wheat yield was consistently higher in CONV than in R-T. In Study II, spring wheat yield in ALT was significantly higher than in CONV and M-T in the last two years of the study. Barley yield in Study II was higher in CONV in most years. Oat yield generally did not follow precipitation trends, and was influenced primarily by the position of oats in the ALT rotations (oats followed high nitrogen-use crops in both systems). Yields of alfalfa in Study I and clover (green manure) in Study II generally followed precipitation trends. The farming system generally did not significantly influence elemental composition (N, P, and K) of grains and oilseeds. A more detailed discussion of crop yields for 1986-1992 was reported in Smolik et al. (1993).

Whole-farm productivity. The ALT systems were 4-year rotations, whereas the CONV, R-T and M-T systems were 3-year rotations. Therefore, assuming equal size farms (540A), the production of an individual crop common to all systems within a study was less in the ALT systems, mainly because less land was planted to each crop (Tables 3 and 4). Because of the different crops and lengths of rotations, we also measured the whole-farm productivity of the systems by comparing crop mass (total dry weight of all plant material) removed from each, and by comparing TDN (total digestible nutrients if all harvested plant materials were fed to ruminant livestock). Although all crops produced in these systems would not normally be fed to ruminant livestock, TDN is another method of comparing systems with different crops and rotations.

In Study I, the crop mass removed on a whole-farm basis was highest in ALT in all years of the studies (Fig. 2), and on average was 57% and 72% higher than in CONV and R-T, respectively (Table 3). Including alfalfa in ALT substantially improved total productivity. The TDN produced in ALT was only 23% and 34% higher than in CONV and R-T, respectively, and reflected the lower digestibility of alfalfa forage compared with grains and oilseeds.

Table 3. Average whole-farm production of systems in Study I, 1986-1992; 540 tillable acres, set-aside met each year.[1]

	Alternative	Conventional	Ridge till
Production			
Corn (bu)	9,678	14,772	14,150
Soybeans (bu)	3,381	4,373	3,756
Spring wheat (bu)	—	6,443	5,563
Oats (bu)	7,003	—	—
Alfalfa (tons)	579	—	—
Crop mass removed (dry wt. tons)[2]	994	632	578
TDN (tons)[3]	684	558	511
Acres per crop (avg.)	127	162	162

[1] Over the 7-yr period, set-aside averaged 10% per year in CONV and R-T, and 6% in ALT.
[2] Conversions to dry weight based on No. 2 corn at 56 lb/bu and 15.5% moisture, soybeans and spring wheat at 60 lb/bu and 13% moisture, and oats at 32 lb/bu and 13% moisture.
[3] Total digestible nutrients produced assuming all grain, oilseeds, and alfalfa forage were fed to ruminant livestock.
Digestibilities: corn = 90%; whole soybeans = 82%; spring wheat and oats = 89%; alfalfa= 55% (J. Wagner, Ruminant Livestock Specialist, SDSU, personal communication).

Table 4. Average whole-farm production of systems in Study II, 1986-1992; 540 tillable acres, set-aside met each year.[1]

	Alternative	Conventional	Minimum till
Production			
Soybeans (bu)	3,994	4,633	4,222
Spring wheat (bu)	5,606	6,403	6,332
Barley (bu)	—	10,202	8,333
Oats (bu)	7,900	—	—
Crop mass removed (dry wt. tons)[2]	361	501	449
TDN (tons)[3]	314	429	385
Acres per crop (avg.)	135	162	162

[1] Set-aside averaged 10% per year in CONV and M-T. The unharvested clover (green manure) in ALT comprised 25% of the cropland and always exceeded set-aside requirements.
[2] Conversions to dry weight based on soybeans and spring wheat at 60 lb/bu, oats at 32 lb/bu, and barley at 48 lb/bu (all crops at 13% moisture).
[3] Total digestible nutrients produced assuming all crops were fed to ruminant livestock.
Digestibilities: whole soybeans = 82%; spring wheat and oats = 89%; barley = 85% (J. Wagner, Ruminant Livestock Specialist, SDSU, personal communication).

In Study II, productivity was generally less in ALT than in CONV and M-T (Fig. 2). Except for the 1991 scab epidemic, productivity in all systems was related to growing season precipitation (Fig. 1). The average crop mass removed was 20% and 28% less in ALT than in M-T and CONV, respectively, and TDN production was 19% and 27% less (Table 4). Although production in ALT generally was lower, if we consider that it did not use the fertilizer and herbicide inputs of the other systems (Table 2), it was surprisingly high. Apparently the clover (green manure) was a good substitute for the more usual inputs used in CONV and M-T.

Production in the reduced-till systems (R-T and M-T) generally was similar to that of the corresponding CONV system in both studies in the earlier years (1986-1990), but lower in the last two years (Fig. 2). The lower soybean yield in the reduced-till systems contributed to the decline in productivity in these systems. The decline in productivity of the reduced-till systems is an example of the importance of long-term studies in evaluating different farming systems. The variability in productivity of the ALT systems in both studies, as measured by the percentage deviation from the mean of the respective system, was less than that of the CONV and reduced-till systems (in Study I the range was +33% to -43% for ALT, +30% to -72% for CONV, and +32% to -64% for R-T; in Study II it was +32% to -42% for ALT, +45% to -57% for CONV, and +35% to -51% for M-T).

We also compared the livestock feed potential of the systems in Study I by assuming that all alfalfa, corn, and soybean meal produced in the systems was fed to ruminant livestock. TDN production in ALT was 47% and 57% higher than in CONV and R-T, respectively, and protein production in ALT was 2 to 2.25 times higher. The alfalfa TDN was equivalent to approximately 15,000 bu of corn, which would more than compensate for the reduced corn production in ALT (Table 3).

We also compared return on investments. In Study I, the crop mass removed per dollar invested in all production costs, including land and labor, was 32 lb/$ in

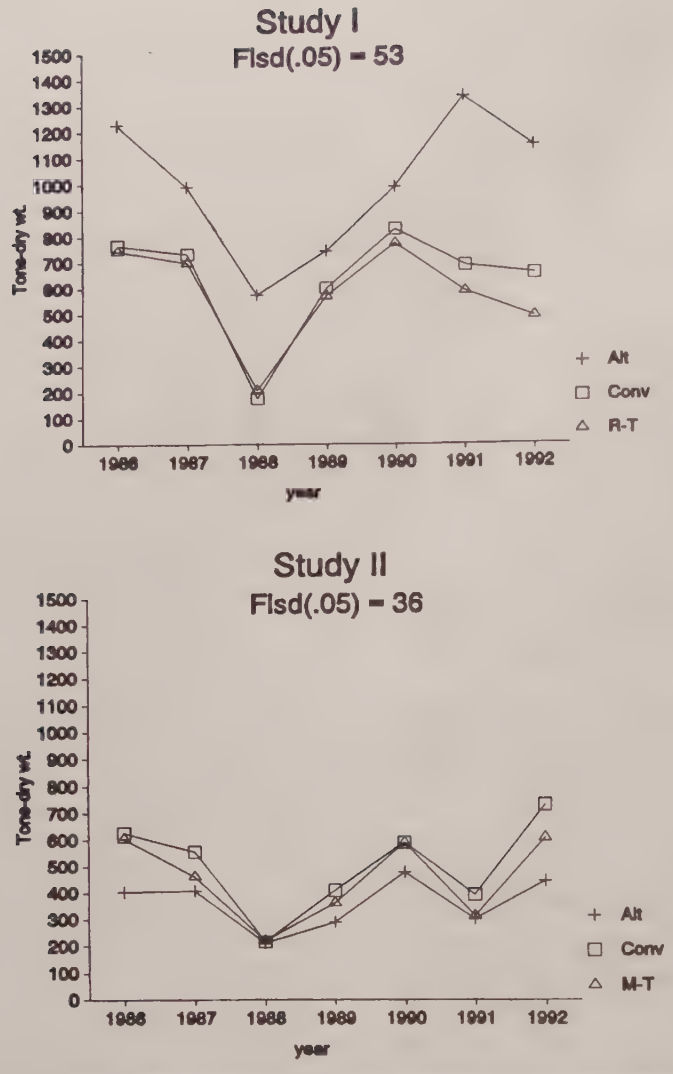


Figure 2. Crop mass (total dry weight of plant material) removed from systems on a whole-farm basis (540A), 1986-1992.

ALT, compared with 18 lb/$ in CONV and 16 lb/$ in R-T. In Study II, the range in crop mass removed per dollar invested in the various systems was comparatively narrow (14-16 lb/$), and crop mass removed was highest in CONV and lowest in M-T.

Energy use. Fuel, fertilizer, pesticides, and their transportation account for a large fraction of the energy inputs in the region's farming systems (Goering and Daugherty, 1982; Keeney and DeLuca, 1992). Energy consumed for fuel, N fertilizer, pesticides, and their transportation in the ALT system in Study I was 68% and 71% less on a whole-farm basis than in CONV and R-T, respectively. In Study II, ALT used 70% and 75% less energy for these inputs than did CONV and M-T, respectively. The least energy-efficient systems in both studies were the reduced-till; although they used less fuel, their higher fertilizer and herbicide use (Tables 1 and 2) more than offset the fuel savings. In Study I, crop mass removed from the system per unit of energy consumed for the inputs listed above was 5 to 6 times higher in ALT than in CONV and R-T. In Study II, ALT was approximately 2 to 3 times more productive per unit of energy consumed than CONV and M-T. Overall, the ALT systems were more energy efficient and were less dependent on nonrenewable energy sources.

Weed populations. Seasonal and long-term weed control are major concerns of farmers when herbicide use is reduced. In the ALT systems, cultivation and inclusion of forage legumes (alfalfa or clover) in the rotations replaced herbicides; in the CONV and reduced-till (R-T and M-T) systems, herbicides were supplemented by cultivation. We counted weed populations in July and October each year to determine seasonal control.

In all systems, *Setaria* spp. (green and yellow foxtail) were the predominant grassy weeds. These weed populations increased in corn in the Study I ALT system later in the study and in R-T in the final year. Populations of perennial weeds, primarily quackgrass (*Elytrigia repens*) and Canadian thistle (*Cirsium arvense*), increased in the reduced-till systems, particularly in the final two years of the study, requiring the use of broad-spectrum herbicides for their control (Tables 1 and 2). Annual broadleaf weed populations were highly variable and did not show significant trends. In general, weed populations were more influenced by weather than by farming system (Rickerl et al., 1994).

Plant diseases. Incidence of common root rot (caused by *Cochliobolus sativus*) in spring wheat was higher in R-T than in CONV. Barley yellow dwarf virus, *Fusarium* head scab, and foliar diseases (primarily rusts, caused by *Puccinia* spp.) all reached damaging levels in some years of the studies in small grain crops, but disease levels usually were not different among systems.

Dagger nematode (*Xiphinema americanum*) was most abundant in the ALT and reduced-till systems in both studies, particularly in the later years. The use of a moldboard plow appeared to be the main reason for the consistently low populations in the CONV systems. Preliminary greenhouse experiments showed that dagger nematodes may have reduced corn and soybean yields in the ALT and reduced-till systems.

Soil water. Fall soil water content in Study I was not very different among systems, but was influenced primarily by crop. For instance, soil moisture in ALT was lowest in the oats-alfalfa plots, which might be expected, since they were the only plots that contained actively growing plants at the time of sampling. Clover was mowed and chisel plowed at mid-season in

the ALT system in Study II, which allowed for additional soil water recharge. This may have been responsible in part for the less variable production in that system.

Nutrient relationships. In South Dakota, N and P are the major fertilizer inputs. The ALT systems relied primarily on forage legumes (alfalfa and clover) and livestock manure (in Study I) for nutrients, while the others relied primarily on commercial fertilizers applied as recommended according to soil test results and moderate yield goals (for example, 50 to 60 bu/A for spring wheat and 100 to 120 bu/A for corn). All systems in these studies included legumes in the rotations.

The removal of N compared with the amount supplied by legumes, livestock manure, and commercial fertilizer on a whole farm basis (540 A) is summarized in Table 5. When all crops are considered, more N was removed than supplied in all systems. Since some legume N came from the atmosphere, we also compared the N removed by non-leguminous crops only. The only system in which removal by non-legumes exceeded supply was CONV in Study II (Table 5). However, considering the N supplied by decomposition of soil organic matter, it appears that all systems had adequate amounts of N.

The relationship between P removal and supply varied considerably among systems. In Study I, P removal in ALT, CONV, and R-T, respectively, was 1.2, 13.7 and 11.8 times greater than the amount supplied. In Study II, P removal in ALT was 3.5 times greater than the amount supplied, while P removal in CONV and M-T was approximately 9 times greater than P supplied. Therefore, the ALT systems in both studies supplied a greater fraction of the P removed than did the more conventional systems.

Table 5. N removed from the systems on a whole farm basis, as % of the total amount supplied by legumes, livestock manure, and commercial fertilizer.

Study and system		Nitrogen removed	
		All harvested crops	Nonleguminous crops
I	Alternative	124	22
	Conventional	129	75
	Ridge till	108	65
II	Alternative	132	61
	Conventional	186	102
	Minimum till	133	72

Economic relationships

Crews et al. (1991) have defined agricultural sustainability in ecological terms. They argue that if ecologically sustainable systems are not profitable to farmers, then we should attempt to restructure society in a way that makes them profitable, rather than declaring them unsustainable because they do not presently satisfy both ecological and economic performance criteria. If farmers are to adopt more ecologically sustainable systems voluntarily, those systems normally must be as attractive as conventional systems from the standpoints of profitability and risk. Therefore, we present our profitability and risk comparisons and discuss the possible implications of the different systems for farm size. For those concerned about the present and future structure of agriculture, farm size implications are critical.

Profitability. In the period 1986-1992, direct costs other than labor averaged from 27% to 49% less for the ALT systems than for the conventional and reduced-till systems (Table 6). In Study I, gross income was highest on average for ALT, followed closely by CONV. In Study II, CONV had the highest average gross income and ALT the lowest. One-fourth of the cropland in ALT in Study II was a non-cash green manure crop (clover), which more than met government set-aside requirements. This explains at least part of the system's low average gross income.

Net income was calculated three ways (Table 6): the first deducted all costs except land, labor, and management (planning, organizing, marketing, etc.); the next also deducted the cost of labor, including family labor; and the last deducted all costs except management. The final column in Table 6 compares net income over all costs except management on a whole farm (540 A) basis.

On average, ALT was the most profitable system in Study I. Net income over all costs except management averaged $37/A for that system, compared with $23/A for CONV and only $6/A for R-T. In Study II, average net income was almost identical for ALT ($12/A) and CONV ($13/A). M-T in Study II lost money ($6/A) when all costs were included. The federal farm program during the study period affected the net income of the various systems differently, with ALT receiving an average of $9/A less per year in government payments than the other systems in Study I, and ALT in Study II an average of $4/A less (Dobbs, 1994).

The average price of alfalfa during the study period ($53/ton) was 10% higher than the 20-year average, which contributed to the solid economic performance of ALT in Study I. Therefore, we conducted a supplemental analysis using synthetic budgets to determine the effect of including alfalfa in the CONV and R-T systems. Including conventionally grown alfalfa (longer-term stands) in the crop mix of CONV (with the same amounts of cropland and the same yields as in ALT) caused CONV in Study I to be slightly more profitable (by $2/A) than ALT. Including alfalfa in the crop mix of R-T also substantially increased its profitability; however, it still left it $11/A less profitable than ALT.

This supplemental analysis of alfalfa involved less reliable production estimates than the rest of the economic analysis, which was based on actual practices, input use, and yields. For example, the assumed yield in the supplemental analysis for an alfalfa stand harvested for four years may have been unrealistically high compared with the younger stand (one year of harvest) in ALT.

Table 6. Average economic results in the Farming Systems Studies (1986-1992).

	Direct costs other than labor ($/A)	Gross income ($/A)	Net income ($/A) over all costs except			Whole farm net income over all costs except management ($)[1]
			Land, labor and management	Land and management	Management	
Study I						
Alternative (oats/alfalfa/ soybeans/corn)	45	153	75	63	37	20,139
Conventional (corn/soybeans/ spring wheat)	62	151	58	49	23	12,328
Ridge till (corn/soybeans/ spring wheat)	69	139	41	32	6	3,149
Study II						
Alternative (oats/clover/ soybeans/spring wheat)	30	101	47	38	12	6,443
Conventional (soybeans/spring wheat/barley)	48	127	49	39	13	6,803
Minimum till (soybeans/spring wheat/barley)	59	116	29	20	-6	-3,360

[1] For farm with 540 tillable acres.

The possibility of including more alfalfa in cropping systems raises the issue of potential adverse effects on hay prices. A 20% decrease in the price of alfalfa hay lowered the profitability of ALT in Study I, but it remained more profitable than the systems without alfalfa (Henning and Dobbs, 1993). A decrease of more than 20% would erode the profitability of ALT compared with CONV even more severely. However, the fear of falling hay prices may be exaggerated, since any widespread conversion to alfalfa-based rotations is likely to be gradual and would probably be accompanied by changes in other factors, such as livestock rations and the location of livestock production. These changes would tend to mitigate the decrease in the price of alfalfa hay.

Risk. One measure of the risk associated with different farming systems is the variability of net income over time. Net income over all costs except management (here referred to in abbreviated form as "net returns to management") was much less variable for ALT than for CONV and R-T in Study I (Fig. 3). The standard deviation for ALT was $16.6/A, compared with $31.3/A for CONV and $29.6/A for R-T. ALT never had negative net returns; this downside risk protection is an important consideration for most farmers.

Variability of net return was about the same for all systems in Study II, with standard deviations of $18.3/A for ALT, $19.3/A for CONV, and $17.2/A for M-T. Both ALT and CONV had negative net returns in two years, compared with four years out of seven for M-T (Fig. 3).

Farm size. There currently is a great deal of interest in how different farming systems affect farm size and the resulting structure of agriculture (Bird, 1992; Smith, 1992). Many factors affect farm size, including the farm's ability to generate adequate levels of family income. Therefore, we analyzed potential farm size implications of the labor and management returns associated with systems in this study (Dobbs, 1993).

Using the whole farm budget data underlying Table 6 and data on labor intensiveness, we computed net returns to labor and management for each system. The opportunity costs charged for land were the same for all systems. In Study I, labor intensiveness was highest for ALT and lowest for R-T; in Study II, it was highest for CONV and lowest for ALT (Dobbs, 1994). Computed net returns to labor and management in Study I were $26/hr for ALT, $19/hr for CONV, and $8/hr for R-T. In Study II, they were $14/hr for ALT, $13/hr for CONV, and $1/hr for M-T.

Since the reduced tillage systems (R-T in Study I and M-T in Study II) had the lowest returns per hour of labor and management and relatively low labor use per acre (lowest in Study I and intermediate in

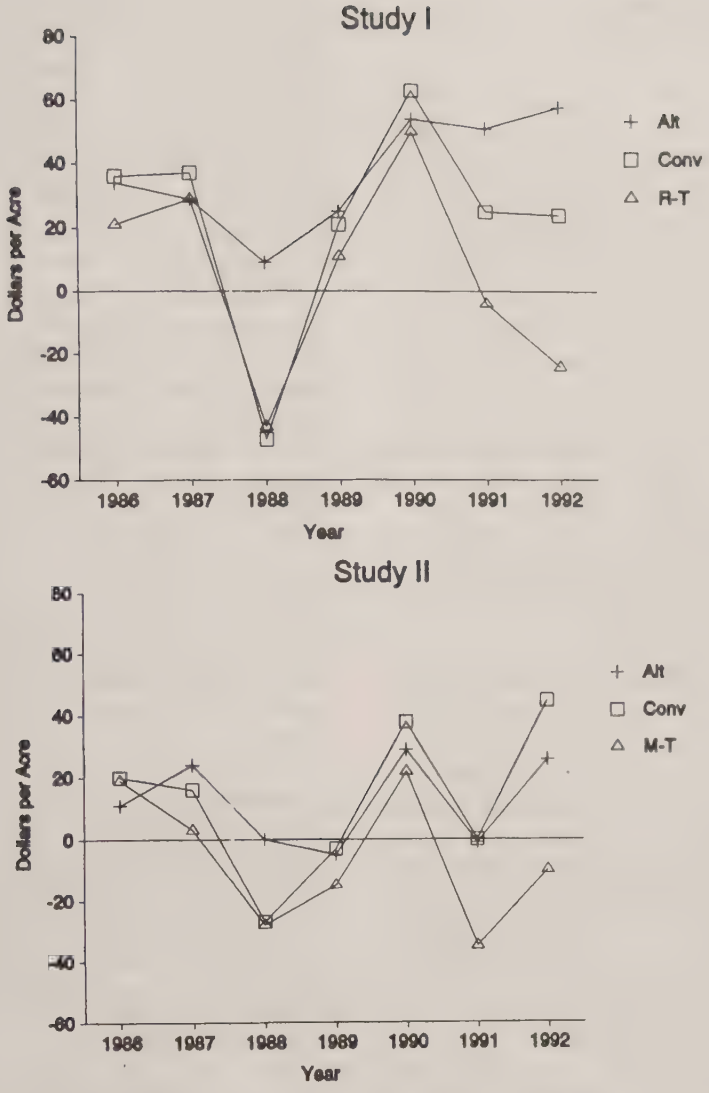


Figure 3. Net returns to management in Study I and II, 1986-1992.

Study II), continued movement toward reduced tillage could exacerbate the growth in farm size in the Northern Plains. Very large farm sizes may be needed to generate reasonable levels of family income.

On the other hand, suppose alternative systems gradually replaced conventional systems in the Northern Plains. We used data for the ALT and CONV systems of Studies I and II to examine the potential farm size implications of such a shift in the study area. We assumed that 1,200 hours of family labor was available per growing season in Study I and 1,040 hours in Study II (less than in Study I because of the shorter growing season associated with rotations consisting primarily of small grains). Labor above that amount would have to be hired, at an assumed rate of $8/hr, including fringe benefits. We then asked how large the farms would need to be in each system to generate a $40,000/yr net return to family labor and management.

In Study I, where systems included substantial amounts of corn and soybeans and where labor intensiveness was greater for ALT, a CONV farm would have had to be nearly twice as large (1,655 A) as an ALT farm (875 A) to generate $40,000 in net returns. On the other hand, in Study II, where systems consisted primarily of small grains, labor intensiveness was lower for ALT and there was little difference between systems in returns per hour of labor and management. Therefore, the implied difference in farm size was much less in Study II; to net the family $40,000, an ALT farm would need 3,342 A, compared with 3,727 A for a CONV farm.

Implications for Sustainability

Response to environmental stress

Growing season precipitation had the greatest influence on production in all systems; the study period included the wettest year in the history of the Northeast Station and the fifth driest year, and in the last year of the study, the coolest July temperatures ever recorded in South Dakota. Plant diseases, primarily barley yellow dwarf virus and *Fusarium* head scab, also significantly influenced small grain yields in all systems in some years. In the later years, weeds and dagger nematodes appeared to influence yields in the ALT and reduced-till systems. The variability in production in the systems over a long-term period provides a measure of the response of the systems to biotic and abiotic stress. Production of crop mass in both studies was less variable in ALT than in the CONV and reduced-till systems.

CONV and R-T in Study I had similar crops in their rotations, as did CONV and M-T in Study II. The main difference between the systems was the intensiveness of tillage. In the earlier years of the studies, production was not substantially different between these systems, but in the last two to three years production was significantly lower in the reduced-till systems. The decline in productivity in the reduced-till systems raises a question about their long-term sustainability in this agro-climatic area.

Overall, these studies showed that production in the ALT systems is likely to remain more stable over a range of climatic and biological stresses. Also, it is noteworthy that the greatest impacts on production in all systems were from weather and pests. Increased research emphasis in areas such as plant disease control may offer the greatest opportunity for improving the productivity of regional farming systems.

Energy use

Energy consumed for fuel, fertilizers, pesticides, and their transportation in the CONV and reduced-till systems was 3 to 4 times higher than in the ALT systems. Higher energy consumption accompanied by a proportionally higher productivity might not be a concern; however, productivity computed as either crop mass removed or TDN produced per unit of energy consumed for the above inputs was 2 to 6 times greater in the ALT systems than in the CONV and reduced-till systems.

Soil erosion and pollution potential

Water quality concerns in this region include increased sediment load and eutrophication of surface waters from N and P in runoff, and contamination of groundwater from nitrate and pesticide leaching. We measured surface residues in all systems; the ALT and reduced-till systems provided very good protection of the soil surface. The inclusion of forage legumes in the ALT systems, coupled with selected aspects of reduced tillage, provided substantial surface residue cover in these systems. The ALT and reduced-till systems were the only systems that consistently met or exceeded current conservation compliance regulations for residue cover on highly erodible land (30% post-plant spring residues). Therefore, both types of systems should adequately address soil erosion concerns and may help limit N and P in runoff.

We removed soil cores to a depth of four feet and measured nitrate-N levels in the last year of Study I. Nitrate-N in CONV and R-T were about 2 to 3 times higher than in ALT. Higher N levels may not necessarily indicate an environmental problem if groundwater is not vulnerable, or if the N is in the upper layers of the soil profile, where it can readily be used by crops. However, most of the NO_3-N in CONV and R-T was below two feet. These studies suggest that the potential for nitrate-N pollution of groundwater was much greater in CONV and R-T than in ALT. We did not measure the potential pollution associated with herbicide use in the conventional and reduced-till systems, either by movement through soil or as residues on crops.

Economic performance and farm size implications

Average net return in Study I was highest for ALT. Also, net return to management was much less variable for ALT than for CONV and R-T, and was never negative for ALT in the 1986-1992 period. Net return to management was negative one year for CONV and three years for R-T.

In Study II, average net return was nearly equal for ALT and CONV. Those two systems also were similar in the variability of their net returns. M-T had much lower net return to management. During the 7-year study period, net return to management was negative twice for both ALT and CONV, and four times for M-T. On average, M-T could not cover all costs when charges for both land and labor were included.

Alternative farming systems also have potentially favorable effects on farm size and the structure of agriculture. Study I contained combinations of corn, soybeans, and small grains. These farming systems represent the western edge of the Corn Belt in the northern Great Plains. Here it appears that widespread adoption of alternative farming systems would tend to halt or at least slow the trend of ever-increasing farm size. In small grain areas of the Northern Plains, represented by the farming systems in Study II, the potential effects are less clear. Some alternative systems are less labor intensive than conventional systems in wheat areas, which might encourage larger farms for the alternative systems. However, our analysis shows that net returns to labor and management could enable alternative farmers to meet family income goals with about the same or slightly less land than conventional farmers. Moreover, the alternative systems are less likely to lead us to ever-larger farms than are the reduced tillage systems.

Relative sustainability and implications for other agro-climatic regions

Regarding the previously mentioned sustainability concerns, the ALT and reduced-till systems both would reduce soil erosion, but the reduced-till systems rate poorly by the other criteria. The CONV systems were more productive than the reduced-till systems, but they may increase soil erosion. Also, they used energy inefficiently, potentially were polluting, and had highly variable production. The CONV and reduced-till systems also depended more on government program payments for their profitability than did the ALT systems. The ALT systems rated favorably regarding all concerns and seem more sustainable in this agro-climatic area.

As indicated earlier, the comparative performance of different farming systems varies substantially across agro-climatic regions. Our results suggest that certain organic systems are attractive from agronomic, economic, and ecological perspectives in the transition zone between the mesic region of corn, soybeans, and hogs and the drier region of cattle, wheat, and sorghum. Perhaps these results suggest what may occur in other regions, such as the Corn Belt, as public policies and sustainable agriculture technologies evolve further.

Acknowledgments. We appreciate the helpful review comments provided by our SDSU colleagues, George Buchenau, James Doolittle, and Donald Taylor. Thanks also to Kathleen Painter and an anonymous reviewer for their valuable comments. This research was supported in part through USDA agreement No. 92-COOP-1-7266. Any opinions, findings, conclusions, or recommendations expressed herein are those of the authors and do not necessarily reflect the views of South Dakota State University or the U.S. Department of Agriculture.

References

1. Ananth, S. 1992. Effect of management practices on vesicular-arbuscular mycorrhizal (VAM) spore distribution and root infection in field-grown crops. Ph.D. Dissertation, Dept. of Plant Science, South Dakota State Univ., Brookings.
2. Batte, M.T. 1992. Sustainable agriculture and farm profitability: The case of organic farming in Ohio. Presented at the Annual Meeting of the Amer. Agric. Economics Assoc., Baltimore, Maryland.
3. Bird, A. 1992. Virtual large farms and exurban communities: Keys to sustainable agriculture. Choices 7(3):54-55.
4. Chase, C., and M. Duffy. 1991. An economic comparison of conventional and reduced-chemical farming systems in Iowa. Amer. J. Alternative Agric. 6:168-173.
5. Crews, T.E., C.L. Mohler, and A.G. Power. 1991. Energetics and ecosys-

tem integrity: The defining principles of sustainable agriculture. Amer. J. Alternative Agric. 6:146-149.
6. Diebel, P.L., R.V. Llewelyn, and J.R. Williams. 1993. A yield sensitivity analysis of conventional and alternative whole-farm budgets for a typical northeast Kansas farm. Presented at the Annual Meeting of the Western Agric. Economics Assoc., Edmonton, Canada.
7. Dobbs, T.L. 1993. Implications of sustainable farming systems in the Northern Great Plains for farm profitability and size. Presented at the Annual Meeting of the Amer. Agric. Economics Assoc., Orlando, Florida.
8. Dobbs, T.L. 1994. Organic, conventional, and reduced till farming systems: Profitability in the northern Great Plains. Choices 9(2):31-32.
9. Dobbs, T.L., D.L. Becker, and D.C. Taylor. 1991a. Sustainable agriculture policy analyses: South Dakota on-farm case studies. J. Farming Systems Research-Extension 2:109-124.
10. Dobbs, T.L., J.D. Smolik, and C. Mends. 1991b. On-farm research comparing conventional and low-input/sustainable agricultural systems in the northern Great Plains. In G.J. Rice (ed). Sustainable Agriculture Research and Education in the Field. National Academy Press, Washington, D.C. pp. 250-265.
11. Dobbs, T.L., D.C. Taylor, and J.D. Smolik. 1992. Farm, rural economy, and policy implications of sustainable agriculture in South Dakota. Bull. 713. South Dakota Agric. Exp. Sta., Brookings.
12. Goering, C.E., and M.J. Daugherty. 1982. Energy accounting for eleven vegetable oil fuels. Trans. Amer. Soc. Agric. Engineers 25:1209-1215.
13. Helmers, G.A., M.R. Langemeier, and J. Atwood. 1986. An economic analysis of alternative cropping systems for east-central Nebraska. Amer. J. Alternative Agric. 1:153-158.
14. Henning, L.D., and T.L. Dobbs. 1993. Contributions of alfalfa to whole-farm profitability of farming systems in northeastern South Dakota. Research Rep. 93-3. Economics Dept., South Dakota State Univ., Brookings.
15. Ikerd, J., S. Monson, and D. VanDyne. 1993. Alternative farming systems for U.S. agriculture: New estimates of profit and environmental effects. Choices 8(3):37-38.
16. Keeney, D.R., and T.H. DeLuca. 1992. Biomass as an energy source for the midwestern U.S. Amer. J. Alternative Agric. 7:137-144.
17. Rickerl, D.H., and J.D. Smolik. 1989a. The effects of farming systems on mycorrhizae. South Dakota Academy of Sci. 68:41-46.
18. Rickerl, D.H., and J.D. Smolik. 1989b. Tillage and crop residue effects on soil frost depth. Proc. Frozen Soil Symposium, Spokane, Washington. pp. 31-35.
19. Rickerl, D.H., and J.D. Smolik. 1990. Farming systems influence on soil properties and yield. J. Soil and Water Conservation 45:121-125.
20. Rickerl, D.H., J.D. Smolik, T.A. Machacek, and S.A. Clay. 1994. Weed ecology in northern plains farming systems. Proc. Agricultural Research to Protect Water Quality, Vol. 2. Soil and Water Conservation Soc., Ankeny, Iowa. pp. 643-655.
21. Sahs, W.W., and G. Lesoing. 1985. Crop rotations and manure versus agricultural chemicals in dryland grain production. J. Soil and Water Conservation 40:511-516.
22. Smith, S. 1992. Farming - It's declining in the U.S. Choices 7(1):8-10.
23. Smolik, J.D., and T.L. Dobbs. 1991. Crop yields and economic returns accompanying the transition to alternative farming systems. J. Production Agric. 4:153-161.
24. Smolik, J.D., T.L. Dobbs, D.H. Rickerl, L.J. Wrage, G.W. Buchenau, and T.A. Machacek. 1993. Agronomic, economic, and ecological relationships in alternative (organic), conventional, and reduced-till farming systems. Bull. 718. South Dakota Agric. Exp. Sta., Brookings.
25. Stanhill, G. 1990. The comparative productivity of organic agriculture. Agric., Ecosystems and Environment 30:1-26.

UPCOMING EVENTS

April 8-25, Tillers International will hold workshops and an international development course; workshops are: *Ox Training*, **April 8**; *Woodwrighting–Forks & Rakes*, **April 8**; and Blacksmithing, **April 11**; *Animal-Powered Development* (development course), **April 25-29**; contact Tillers, 5239 South 24th St., Kalamazoo, MI 49002; (616)344-3233.

April 14 is the deadline for abstracts for papers for *Environmental Enhancement Through Agriculture*, organized in part by the Wallace Institute, to be held in Boston, MA, November 16-17; contact William Lockeretz, School of Nutrition, Tufts University, Medford, MA 02155; (617)627-3223; e-mail wlockeretz@infonet.tufts.edu

April 21-May 4, *Permaculture Design Course* will be held at Fossil Rim Wildlife Center; contact Fossil Rim, P.O. Box 2189, Glen Rose, TX 76043; (817)897-2960.

May 1-2, *Risks, Regulations, and Resolutions: Creating the Process*, the Wildlands Conference, will be held in Dearborn, MI; contact Wildlife Habitat Council, 1010 Wayne Ave., #920, Silver Spring, MD 20910; (301)588-8994.

May 8-10, *Planning for a Sustainable Future: The Case of the North American Great Plains* will be held in Lincoln, NE; contact Dr. Donald A. Wilhite, Director, International Drought Information Center, P.O. Box 830728, University of Nebraska, Lincoln, NE 68583-0728; (402)472-6707; e-mail agme002@unlvm.unl.edu

May 29-June 1, *Sustainable Forests: Global Challenges and Local Solutions* will be held in Saskatoon, Saskatchewan, Canada; contact Dr. Thomas Bouman, Prince Albert Model Forest Assoc. Inc., Box 2406, Prince Albert, SK, Canada S6V 7G3; (306)922-1944.

August 5-10, *Quality of Soil and Plant Analysis in view of Sustainable Agriculture and the Environment* will be held in Wageningen, the Netherlands; contact International Agricultural Centre, Section Organization Courses and Conferences, P.O. Box 88, 6700 AB, Wageningen, the Netherlands; phone +31-8370-90287.

Soil quality and profitability of biodynamic and conventional farming systems: A review

John P. Reganold

Abstract. *Biodynamic and organic farming are similar in that both are ecologically oriented and do not use chemical fertilizers and pesticides. The main difference is that biodynamic farmers add eight specific amendments, called preparations, to their soils, crops, and composts. Recently, there has been an increasing interest in biodynamic farming practices and systems because they show potential for mitigating some detrimental effects of chemical-dependent conventional agriculture. Only a few studies examining biodynamic methods or comparing biodynamic farming with other farming systems have been published in the refereed scientific literature, especially in English. This paper summarizes data from previous studies, both published and unpublished (theses), that have compared biodynamic and conventional farming systems with respect to soil quality or profitability. These studies have shown that the biodynamic farming systems generally have better soil quality, lower crop yields, and equal or higher net returns per hectare than their conventional counterparts. Two studies that included organic management treatments with and without the preparations showed that the preparations improved biological soil properties and increased crop root growth. However, more research is needed to determine whether the preparations affect soil physical, chemical, and biological properties and crop growth and, if so, their mode of action.*

Key words: biodynamic farming, biodynamic preparations, soil quality, farm profitability, cropping systems, on-farm research, sustainable agriculture

Introduction

Growing concerns about the environmental, economic and social effects of chemical-dependent conventional agriculture have led many farmers and consumers to seek alternative practices and systems that will make agriculture more sustainable. Alternative farming systems include "organic", "biological", "biodynamic", "ecological", and "low input." However, just because a farm is "organic" or "biodynamic," for example, does not mean that it is sustainable. To be sustainable, it must produce adequate food of high quality, be environmentally safe, protect the soil, and be profitable and socially just (Reganold et al., 1990).

Recently, there has been increasing interest in biodynamic farming and gardening. For example, between 1989 and 1992 the number of biodynamic farms in France increased from 142 to 202 (Bio-Dynamic Farming and Gardening Association in New Zealand, 1993). Although biodynamic farming is practiced in cool and warm climates on all continents, the highest proportions of biodynamic farms are found in Western Europe, Australia, New Zealand, and North America (Lampkin, 1990). A mid-1980s survey in Europe found 1,090 commercial biodynamic farms and gardens on 17,616 ha; 42% of these were in Germany and 15% in Holland (Koepf, 1989). The survey also found that the European biodynamic movement included 28 full-time advisors, 124 processors under contract, 47 wholesalers, about 3,000 retailers, 30 consumer groups, and many additional part-time biodynamic farmers and gardeners. A rough estimate is that there are at least 2,000 practicing biodynamic farmers (full- or part-time) and gardeners in the United States today (Charles L. Beedy, Executive Director, Bio-Dynamic Farming and Gardening Association Inc., Kimberton, Pennsylvania, personal communication, August 1994).

Biodynamics is considered by some to be the oldest organized alternative agriculture movement in the world. It began in 1924 following a series of lectures by Rudolf Steiner, the founder of anthroposophy, at the request of German farmers (Koepf, 1989). Within a few years, interest spread to several European countries. Ehrenfried Pfeiffer brought biodynamics to the United States from Europe before World War II. Today, farmers, gardeners, advisers, and scientists are organized into biodynamic associations, some of which have their own research facilities. A certification program was introduced in 1928 for marketing basic foodstuffs, which are now marketed under the trademarks Demeter and Biodyn. Most, if not all, certified biodynamic products (for example, those with the Demeter label) would meet the criteria for certified organic, but certified organic would not meet the Demeter standards, mainly because the biodynamic preparations are not used in organic farming.

Like organic farming, biodynamic farming uses no synthetic chemical fertilizers and pesticides, and instead emphasizes building up the soil with compost additions and animal and green manures, controlling pests naturally, rotating crops, and diversifying crops and livestock. A major difference is that biodynamic farm-

John P. Reganold is Professor, Department of Crop and Soil Sciences, Washington State University, Pullman, WA 99164-6420.

ers add eight specific preparations to their soils, crops, and composts to enhance soil and crop quality and to stimulate the composting process (Koepf et al., 1976). The eight preparations, designated by their ingredients or by the numbers 500 to 507, are made from cow manure, silica, flowers of yarrow, chamomile, dandelion and valerian, oak bark, and the whole plant of stinging nettle (Table 1). Some biodynamic farmers make the preparations themselves, while others buy them from certifying biodynamic associations or experienced practitioners.

The thoughts behind the preparations are unconventional and based on a holistic approach to nature. When applied, extracts of the preparations are so highly diluted in water that physical or biological effects seem unlikely. Yet significant increases in yield have been reported in the biodynamic literature (Goldstein, 1990). Biodynamic practitioners maintain that the preparations are not "witchcraft", "snake oils", "miracle cure-alls", or part of a get-rich-quick scheme. Goldstein (1990) believes that people who doubt that the preparations benefit agriculture do so for the following reasons:

- Most people have probably not heard of biodynamics or biodynamic preparations.
- Biodynamics is based on spiritual-physical principles. Spiritual matters are difficult, if not impossible, to measure.
- The making of the preparations seems strange or unsanitary to many.
- Such small amounts of the preparations are applied to crops, soils, or compost that a response seems unlikely.
- No correct chemical/physical answer to why the preparations may work has been offered. Some have proposed that the preparations act as microbial inoculates; others think they may have hormonal effects or maybe even radiative effects.

Besides the preparations, there are other differences between organic and biodynamic farming. Modern organic farming was started by Sir Albert Howard in England in the 1930s, emphasizing the use of compost instead of chemical fertilizers (Oelhaf, 1978). In 1924, Rudolf Steiner's concept of a healthy agriculture took into account not only crop rotations, sound stocking rates, and organic manuring, but also cosmic factors, namely the influence of the moon and planets. For example, his observations led him to believe that there was a relationship between the position of the moon relative to the sun (synodic rhythm), planting dates, and crop growth (Spiess, 1990).

Although there have been many articles, ranging from the sketchy to the detailed, describing studies of biodynamic practices, most of this information has not been reviewed according to rigorous scientific principles by traditional soil scientists, agronomists, or agricultural economists (Koepf, 1993). Few studies examining biodynamic farming methods or comparing biodynamic with other farming systems have been published in the refereed scientific literature, especially in English. Most such studies have been conducted and published in Germany and Sweden and are not available in English (Koepf, 1989, 1993).

This paper summarizes data from several previous investigations comparing biodynamic and conventional farms or research plots in Europe, Australia, New Zealand, the United States, and the Canary Islands. Since this review includes mostly English publications, it covers only a small portion of the literature on biodynamics. The objective of each study reported here was to determine the effects of biodynamic

Table 1. The eight biodynamic preparations, which consist of fermented materials that are used as field sprays or in manure or compost piles (Proctor, 1989).[1]

Preparation	Substance from which preparation is produced	Application of preparation
500	Cow manure fermented in a cow horn	A spray for soils before planting
501	Silica fermented in a cow horn	A spray for growing crops
502	Flower heads from yarrow (*Achillea millefolium*) fermented in the bladder of a stag	Preparations 502 through 507 are applied to manure or compost piles
503	Flower heads from German chamomile (*Matricaria recutita*) fermented in a cow intestine	
504	Stinging nettle (*Urtica dioica*) fermented in the soil	
505	Oak bark (*Quercus robur*; in North America *Quercus alba*) fermented in the skull of a domestic animal	
506	Flower heads of dandelion (*Taraxacum officinale*) fermented in a cow mesentry	
507	Juice pressed from valerian flowers (*Valeriana officinalis*)	

[1] Although not considered one of the eight main preparations, a ninth preparation, sometimes referred to as 508, is made by boiling the horsetail plant (*Equisetum arvense*) and is applied only in excessively wet years to prevent fungal diseases.

and conventional farming on soil quality or economic performance, two of several indexes of agricultural sustainability.

Soil Quality Studies

High quality soils not only promote the growth of plants, but also prevent water and air pollution by resisting erosion and by degrading and immobilizing agricultural chemicals, organic wastes, and other potential pollutants. The quality of a soil is determined by a combination of physical, chemical, and biological properties such as the soil's texture, depth, porosity, capacity to store water and nutrients, organic matter content, and biological activity (National Research Council, 1993). In this section I report on studies examining different combinations of soil physical, chemical, and biological properties of farms or research plots under biodynamic and conventional management. Some studies also include an organic treatment.

Sweden. In 1958, the Scandinavian Research Circle began a field plot experiment in Järna to study the effects of biodynamic, organic, and conventional management on soil and crop quality (Pettersson and von Wistinghausen, 1979). Eight nonreplicated fertilizer treatments were applied to field plots. Each treatment had the same four-year crop rotation: summer wheat/clover-grass mixture/potatoes/beets (Table 2). Routine soil tests have been carried out since 1958 at 3 to 5 year intervals; detailed analyses were done of the topsoil (0-10 cm) and subsoil (25-35 cm) in 1976, 1985, and 1989, and of the second subsoil layer (50-60 cm) in 1985 and 1989 (Pettersson et al., 1992).

In all three sampling years, the topsoil of the biodynamically treated and organically fertilized plots (K1-K4) generally was higher in organic matter, microbial activity, enzyme activity (dehydrogenase and urease), earthworm channels, total N, and pH than the topsoil of the control (K5) or chemically fertilized plots (K6-K8) (Pettersson et al., 1992). Among the organically fertilized treatments (K1-K4), treatment K4, the only one with both organic and inorganic fertilizers, had the lowest microbial activity, dehydrogenase activity, and earthworm channels for all three years. Extractable P levels were highest in the chemically fertilized treatments (K7 and K8) in all three years.

In the Pettersson et al. study (1992), average yields for all four crops over the 32-year period (1958-1989) were comparable for all treatments, except that the control (K5) was lower and the low NPK treatment (K6) somewhat lower. The variation in yield among the seven treatments other than the control was almost 20%, with the K8 treatment (high NPK) having the highest average yield and the K6 treatment (low NPK) the lowest.

Granstedt (1991) measured plant nutrient inputs and outputs on conventional and biodynamic farms in Sweden. He showed that the nutrient economy on biodynamic farms was more efficient and potentially more environmentally safe than on conventional farms.

Germany. A four-year plot experiment comparing biological soil properties under biodynamic, organic, and conventional vegetable management was carried out in Germany (Abele, 1987, as translated by Koepf, 1993). Each management system received annual applications of N at three different rates (50, 100, and 150 kg/ha), applied as chemical fertilizer to the conventional plots, as composted manure to the organic plots, and as composted manure with biodynamic preparations to the biodynamic plots. At all three N rates, organic matter and total N were significantly higher in the biodynamic plots than in the corresponding organic plots, and in both the biodynamic and organic plots than in the conventional plots. The biodynamic plots also were significantly higher than the organic plots, and the organic plots in turn significantly higher than the conventional plots, in dehydrogenase activity, microbial biomass, and dehydrogenase activity per unit of microbial biomass.

In another plot study on an experiment station in Germany, Reinken (1986) found higher organic matter levels and earthworm populations on biodynamically treated vegetable and apple plots than on conventionally treated vegetable and apple plots.

Austria. Foissner (1987) investigated soil animals, microbial activity, soil enzymes, and other soil properties on two pairs of matched biodynamic and conventional farms near Vienna. The biodynamically farmed soils had greater numbers of protozoa (testate amoebae and ciliates) and nematodes, higher microbial activity and humus content, and lower bulk density

Table 2. The eight treatments in the field plot experiment in Järna, Sweden (Pettersson and von Wistinghausen, 1979).

Treatment	Fertilizer application
K1	Composted manure with biodynamic preparations 502 through 507 and, from 1962 on, 1% levels of meat meal and bone meal (only bone meal after 1974); soils and plants treated with biodynamic preparations 500 and 501, respectively
K2	Same as K1 but excluding biodynamic sprays 500 and 501
K3	Raw manure with 1% additions of horn and bone meal as of 1974
K4	Raw manure at half the K3 rate plus inorganic NPK fertilizer at half the K6 NPK rate
K5	Control (unfertilized)
K6	Inorganic NPK: From 1958 through 1973, compounded from $Ca(NO_3)_2$, NH_4NO_3, superphosphate, and K_2SO_4; from 1974 on, prepared blend (11-5-18) with trace minerals
K7	Inorganic NPK at twice the level as in K6
K8	Inorganic NPK at four times the N level and twice the P and K levels as in K6

than the conventionally farmed soil. However, few differences could be asserted with high statistical confidence because of the low sample size.

Australia. In a comparison of a biodynamic and an adjacent conventional farm in Australia, Forman (1981) examined soil properties, yields, and plant nutrient contents. The two farms were in the Breeza Plains area in New South Wales. The seven-year old biodynamic farm used a crop rotation of wheat/rye/fallow/wheat/fallow/wheat/wheat. The biodynamic paddock was in scattered timber before being cultivated. The 11-year old conventional farm used a wheat/wheat/fallow rotation. Before the conventional paddock was put into arable crops, it first had been farmed for 10 years, then was in pasture for about 35 years. Organic matter, extractable P, and pH were all significantly higher on the biodynamic farm than on the adjacent conventional farm (Table 3). Levels of K were similar; only Mg and Na were lower on the biodynamic farm.

Forman also conducted a greenhouse pot trial with wheat using soil samples from the biodynamic paddock and the conventional paddock. Both soils received various combinations of two biodynamic preparations (500 and 507) and two inorganic fertilizer nutrients (N and P). A total of 16 treatments (including a control), each replicated three times, was applied to pots from both biodynamic and conventional

Table 3. Mean values of soils data from adjacent paddocks and plant data from pot trials, New South Wales Farm Pair, Australia (Forman, 1981).

Soil[1] and Plant Properties	Biodynamic Farm	Conventional Farm
Soil Properties in Field Study		
C (%)	1.43*	0.94
Total Nitrogen (%)[2,3]	0.23	0.13
Extractable P (mg/kg)	44.9*	27.8
Extractable Mg (cmol/kg)	1.65	1.86*
Extractable K (cmol/kg)	1.33	1.39
Extractable Na (cmol/kg)	2.17	4.63*
pH	6.12*	5.57
Pot Study		
Seedling emergence count (7 days after sowing)[3]	111	48
Seedling emergence count (8 days after sowing)[3]	210	165
Plants showing tiller development (13 days after sowing)[3]	86	13
Mass of dry matter wheat produced (g) per pot (48 days after sowing)	2.57*	1.57
Mass of dry matter wheat produced per amount of water added (mg/ml)	1.32*	0.98
Plant N content (%)	2.09*	1.84
Plant N uptake (mg)	55.2*	30.4
Plant P content (%)	0.36	0.46*
Plant P uptake (mg)	9.4*	6.9
Plant Ca content (%)	0.33*	0.25
Plant K content (%)	3.31	3.17
Plant Mg content (%)	0.13	0.12

* indicates a significantly higher value ($p<0.01$, using a two-sided t-test for the field study and a two-way ANOVA in a randomized complete block design for the pot study).

[1] Based on a sampling depth of 0-10 cm.

[2] Total N means are each based on analysis of only two bulked samples per paddock; all other soil properties are averages for 25 separate samples per paddock.

[3] Not statistically analyzed.

soils. Over all treatments, Forman found that the biodynamic soil had higher wheat seedling emergence counts 7 and 8 days after sowing and a much higher rate of tiller formation 13 days after sowing than the conventional soil (Table 3). It also had significantly higher dry matter wheat yields (48 days after sowing) and higher yields per unit of water added (water use efficiency) than the conventional soil. Plants grown in the biodynamic soil had significantly higher N content and uptake, P uptake, and Ca content than plants grown in the conventional soil, but P content was significantly higher in the conventional soil.

Penfold (1993, 1994) established a long-term research project in 1989 at the Roseworthy Campus of the University of Adelaide in Australia to investigate soil characteristics, crop yields, and economics of four farming systems: biodynamic, conventional, integrated (low input), and organic. The systems are being compared in a 16 ha campus farm paddock previously in pasture, with two replicated 2-ha plots per treatment. A wheat crop is grown in all treatments every four years. After four years, the four treatments showed few statistically significant differences in organic C, VA mycorrhizae, microbial biomass and activity, earthworms, water infiltration, soil erosion, or extractable P (Penfold, 1994).

New Zealand. To examine the effects of biodynamic and conventional farming systems on soil quality, Reganold et al. (1993) examined seven biodynamic farms on the North Island of New Zealand, each of which was matched with one or two adjacent conventional farms on the basis of soil characteristics and crop or livestock enterprises (total of 16 farms). The farms included a range of representative enterprises in New Zealand: market garden (vegetables), pipfruit (apples and pears), citrus, grain, sheep/beef, and dairy. Farm fields within each pair or three-farm set had the same crop or livestock enterprise and soil type. The biodynamic farms had been biodynamically managed for at least 8 years, the oldest for 18 years. The biodynamically managed surface soils (0-10 cm) had significantly higher organic matter content and microbial activity, lower bulk density, easier penetrability, and thicker topsoil than their conventional neighbors (Table 4). Differences in chemical properties were mixed: cation exchange capacity and total N were higher on the biodynamic farms, while available P, available S and soil pH were higher on the conventional farms. Levels of Ca, Mg, and K were similar in the two systems.

The physical condition of the soils on all 16 farms has since been assessed (Reganold and Palmer, unpublished data) using a soil structure index developed by Peerlkamp (1967), as modified by McLaren and Cameron (1990). The structure index ranges from 1 (poorest condition) to 10 (most favorable). The index for

Table 4. Mean values of aggregated soils data (Reganold et al., 1993).

Soil property[1]	All biodynamic farms	All conventional farms
Bulk density (Mg/m^3)	1.07	1.15*
Penetration resistance (0-20 cm) (MPa)	2.84	3.18*
Penetration resistance (20-40 cm) (MPa)	3.55	3.52
Soil Structure Index[2]	7.4*	5.7
Topsoil thickness (cm) (includes surface and subsurface (A) horizons)	22.8*	20.6
C (%)	4.84*	4.27
Respiration ($\mu L\ O_2\ h^{-1}\ g^{-1}$)	73.7*	55.4
Mineralizable nitrogen (mg/kg)	140.0*	105.9
Ratio of mineralizable N to C (mg min N/g C)	2.99*	2.59
Cation exchange capacity (cmol/kg)	21.5*	19.6
Total N (mg/kg)	4840*	4260
Total P (mg/kg)	1560	1640
Extractable P (mg/kg)	45.7	66.2*
Extractable S (mg/kg)	10.5	21.5*
Extractable Ca (cmol/kg)	12.8	13.5
Extractable Mg (cmol/kg)	1.71	1.68
Extractable K (cmol/kg)	0.97	1.00
pH	6.10	6.29*

* indicates a significantly higher value ($p<0.01$, using a two-way ANOVA).
[1] Based on a sampling depth of 0-10 cm, except where noted.
[2] Unpublished data (Reganold and Palmer, 1994) based on soil structure index developed by Peerlkamp (1967), as modified by McLaren and Cameron (1990).

the biodynamically farmed soils averaged 7.4, whereas the conventionally farmed soils were significantly lower at 5.7 (Table 4).

Reganold et al. (1993) analyzed only the vegetable farm pair for earthworms and found the biodynamically cropped soil to have more than 8 times as many earthworms (more than 25 times by mass) as the conventionally cropped soil. In later measurements on two of the other farm pairs in the study of Reganold et al. (1993), Levick (1992) found 12 times as many earthworms on the biodynamic citrus farm and 84 times as many earthworms on the biodynamic pipfruit farm compared with their conventional counterparts. Levick also found that the biodynamically farmed soils had significantly higher water infiltration rates, porosity, organic C and soil respiration, and lower bulk density and penetration resistance than the conventionally farmed soils.

United States. Goldstein (1986) compared the effects of biodynamic, organic, and conventional management on biological soil properties and crop growth characteristics in a three-year field plot study in a dryland grain production area of Washington State. The biodynamic plots (manure compost and preparations) and the organic plots (manure compost only) were significantly higher in organic matter and microbial respiration and biomass than were the conventional plots (N and P fertilizer). The biodynamic plots were significantly higher in microbial biomass and slightly higher in organic matter and microbial respiration than the organic plots. The biodynamic plots also had more growth of winter wheat roots than either the organic or the conventional plots.

Canary Islands. Garcia et al. (1989) studied soil fertility and foliar composition on a 5-year old, 6-ha biodynamic avocado plantation in Tenerife (largest of the Canary Islands). They compared the results with similar soil data (gathered 5 years earlier) from 31 conventional avocado plantations and similar foliar data from 15 plantations. They found that the surface soils (0-25 cm) of the biodynamic plantation were significantly higher in pH, organic matter, and available P, Ca, Mg, and K than those of the conventional plantations. Foliar levels of N, P, K, Mg, and Cu were similar in the two types of plantations; Ca and Mn were significantly lower in the biodynamic avocados, although they fell within the range considered normal, and foliar Zn was significantly higher in the biodynamic avocados.

Economic Studies

Researchers in the studies reported here used enterprise gross margin as a measure of economic performance, except for Vereijken (1986; 1990). Gross margin is the difference between gross revenue and variable or operating expenses. Variable costs include fertilizers, pesticides, fuel, labor, and biodynamic preparations, among others. Fixed costs such as debt servicing were excluded.

Germany. Schlüter (1985), at the University of Stuttgart-Hohenheim, Germany, analyzed farm management, labor, yields, and profitability of 16 biodynamic farms from seven production regions in the southwest German state of Baden-Württemberg. (I base this review on a condensed English translation of her dissertation by Koepf [1986].) Schlüter's team gathered data from farm records and from interviews with the farmers every three months for two years (1980-1981). The farms had been under biodynamic management for an average of 14.5 years (6 to 51 years) and averaged 28 ha in size (15 to 49 ha). The biodynamic farms produced cereal crops, row crops (potatoes, sugarbeets and field vegetables), maize for silage, other arable forage (clover/grass, mixtures of legumes with cereals), and livestock (cattle, pigs, poultry, dairy). Results from the biodynamic farms were compared with annual official statistics from the Baden-Württemberg Ministry of Food, Agriculture and Environment for conventional farms in each production region.

The yields of all the cereal crops on biodynamic farms for 1979/1980 and 1980/1981 were lower by 13%, the average being almost equal to conventional farm yields on the good soils and considerably lower on the poorer soils. Koepf (1986) points out that part of this difference may have been due to preference of biodynamic farmers and their customers for certain lower yielding cultivars with desired baking qualities, and to the production of spelt (*Triticum spelta*, or German wheat), hulless oats, and hulless barley for human consumption. Potato yields were similar in the two farming systems. Milk yields per cow on biodynamic farms were almost 15% lower than on the conventional farms. Again, Koepf (1986) notes that this difference may have resulted because biodynamic farmers who wished to qualify for Demeter (biodynamic) certification were allowed to buy commercial feeds only up to 10% of the dry matter content of the ration.

The costs and returns for the biodynamic and conventional farms in the Schlüter study are shown in Table 5. The

Table 5. Gross revenue, expenses, and profits of biodynamic and conventional farms in Germany in 1980 and 1981 (Koepf, 1986).

Farm size:	10-20 ha		20-30 ha		30-40 ha	
	Bio	Con	Bio	Con	Bio	Con
Number of farms	4	928	4	1,689	4	1,612
Average size of farms (ha)	17.7	16.2	22.1	25.0	38.4	37.6
Gross revenue (DM ha^{-1} yr^{-1})	6,369	6,625	6,874	5,774	3,507	4,689
Expenses (DM ha^{-1} yr^{-1})	3,934	5,093	3,713	4,505	2,415	3,755
Profit (DM ha^{-1} yr^{-1})	2,435	1,532	3,161	1,269	1,092	934

biodynamic and conventional farms had similar gross revenues. Gross revenues in German marks (DM) per ha from all crops were higher on the biodynamic farms, whereas gross revenues from animal husbandry (beef, pork, milk and eggs) were 25 to 54% lower on the biodynamic farms (Koepf, 1986). However, because the biodynamic farmers had lower costs than the conventional farmers, their profits were higher (Table 5). In the two years studied, biodynamic products received an average premium of 59% (range 15 to 108%) over the price of similar conventional products (Koepf, 1986).

On research plots at an experiment station in Germany, yields of all vegetable crops for a six-year period averaged 16% less on biodynamic plots than on conventional plots (Reinken, 1986). However, since the prices received were higher for biodynamic than for conventional vegetables, profits were significantly higher for most biodynamic vegetables, including spinach, celery, red beet, white cabbage, and carrot. Reinken (1986) found that average yields of three varieties of apples for the six-year period were 30 to 38% lower on the biodynamic plots than on the conventional plots. Profitability for apples was not reported. Labor requirements for apple growing were an average of 27% higher on the biodynamic plots, but the biodynamic apples received a premium of 27% over the price of conventional apples.

An early study by the Baden-Württemberg Ministry of Food, Agriculture and Environment in Germany (MELU, 1977), as translated and reported in Koepf (1989) and Lampkin (1990), reported results similar to those of the Schlüter and Reinken studies on yields and economic performance. The MELU study surveyed pairs of biodynamic and conventional farms from 1971 to 1974. It found that although the biodynamic farms' grain yields were from 10 to 25% lower, their variable costs were lower and their net returns were about the same to about 40% higher than their conventional counterparts. If the premium prices received by the biodynamic farmers were replaced by the conventional prices, their net returns would have been about 0 to 20% lower than those of their conventional neighbors (Lampkin, 1990).

The Netherlands. Research on alternative and conventional farming systems began in 1979 on a 72-ha experimental farm in Nagele (Vereijken, 1990). Three farming systems were set up as whole farms: a 22-ha biodynamic farm, a 17-ha conventional farm, and a 17-ha integrated farm (minimal inputs of fertilizers and pesticides). Economic data from 1982 to 1985 (Vereijken, 1986) and from 1985 to 1987 (Vereijken, 1990) indicated that gross revenue was the highest for the biodynamic farm because of the high premiums paid for the biodynamic products. However, total production costs also were higher for the biodynamic farm than either the conventional or the integrated farm, which resulted in the biodynamic farm having the lowest net income.

These results contrast sharply with other results discussed in this paper. As pointed out by Lampkin (1990), a major flaw in the Nagele study is that the biodynamic unit was established as a labor-intensive mixed dairy and arable system (11-year crop rotation) in an area that is almost exclusively arable. The conventional and integrated units were set up as arable farms with the same four-year crop rotation. Labor costs for the biodynamic farm were almost three times higher than for either the conventional or integrated farm, causing most of the difference in net returns. Lampkin (1990) concludes that a less labor-intensive organic system could have been developed that would have been more competitive given the conditions in the region.

Australia. In the Penfold study (1993) discussed earlier, conventional yields were highest (3.5 ton/ha) and biodynamic yields were lowest (2.3 ton/ha) in 1992, when all four treatments were in wheat (Table 6). However, the biodynamic treatment had the highest total gross margin per ha for the

Table 6. Rotations (1989-1992), wheat yields (1992), and gross revenue, variable costs, and gross margin (1989-1992) of biodynamic, conventional, integrated, and organic plots in Australia (Penfold, 1993; 1994).

		Biodynamic	Conventional	Integrated	Organic
Rotation:	1989	oats/medic for hay	wheat	oats/medic for hay	oats/medic for hay
	1990	legume-based pasture	peas	legume-based pasture	wheat (mulched)
	1991	oats/vetch for hay	legume-based pasture	legume-based pasture	green manure crop
	1992	wheat	wheat	wheat	wheat
Wheat yield (1992) (t/ha)		2.3	3.5	2.7	2.9
Total over rotation, 1989-1992 (A$/ha)					
Gross revenue		1,399	1,196	823	992
Variable costs		391	436	553	357
Gross margin		1,008	760	270	635

first four years (1989-1992), followed by the conventional, organic, and integrated treatments (Table 6). This included a 20% premium on organic and biodynamic wheat from the 1992 harvest. The biodynamic and conventional treatments had the highest gross margins mainly because they had three cash crops, whereas the organic and integrated treatments had only two.

New Zealand. Reganold et al. (1993) compared the economic performance of biodynamic and conventional farms in the same study that analyzed soil quality. They examined farmers' annual accounts from 1987 to 1991 for 11 of the 16 farms. These results also were compared to representative conventional farm data in annual reports by the Ministry of Agriculture and Fisheries (MAF) for all major farming systems in New Zealand. On a per hectare basis the biodynamic farms were as profitable as the neighboring conventional farms and the representative conventional farms (Table 7). Most of their products were sold as certified organic or biodynamic at premium prices up to 25% above the market prices of similar conventional products. Most of the biodynamic farms had less year-to-year variability in gross revenue than the conventional farms (Reganold et al., 1993). Economic stability is a significant characteristic of sustainable farming systems.

Table 7. Average annual gross revenue, variable costs, and gross margin of biodynamic and conventional farms in New Zealand, 1988 to 1991 (Reganold et al., 1993).

	Average (NZ$ ha^{-1} yr^{-1})		
Farm enterprise	**Bio**	**Con**	**MAF [1]**
Market gardens			
Gross revenue	14,094	18,845	—[2]
Variable costs	4,977	8,088	—[2]
Gross margin	9,117	10,757	—[2]
Citrus orchards			
Gross revenue	13,434	—[3]	13,481
Variable costs	6,254	—[3]	8,974
Gross margin	7,180	—[3]	4,507
Mixed farms			
Gross revenue	703	1,337	1,027
Variable costs	311	537	436
Gross margin	392	800	591
Livestock farms			
Gross revenue	463	393	328
Variable costs	46	83	84
Gross margin	417	310	244
Dairy farm set #1			
Gross revenue	2,283	—[4]	1,355
Variable costs	833	—[4]	426
Gross margin	1,450	—[4]	929
Dairy farm set #2			
Gross revenue	1,696	2,237	1,817
Variable costs	918	503	513
Gross margin	778	1,734	1,304

[1] Representative conventional farm based on New Zealand Ministry of Agriculture and Fisheries.
[2] There are no MAF models for market gardens.
[3] Only two years of financial data were available, so averages are not reported here.
[4] Economic records were not available.

Summary and Discussion

The farming goals of biodynamic practitioners include protection and enhancement of soil to produce high quality products. To stimulate life in the soil and in plants, they use eight specific amendments, called preparations, on their soils and crops and in their composts. Their system includes practices such as green and animal manuring, composting, biological pest controls, reduced tillage, complex crop rotations, and diversified crops and livestock.

This paper has summarized the few studies available in English that have compared soil quality or farm profitability in biodynamic and conventional farming systems. These studies found that the biodynamic farming systems generally had better soil quality, lower crop yields, and equal or greater net returns per hectare than their conventional counterparts. The economic studies showed that biodynamic farming systems can and do work. Many biodynamic farmers stay in business because of the price premium received for their products. Although the studies reported here included these premiums, they did not count the environmental and health costs of the two farming systems, which are external to the farm's accounts. The long-term profitability of many conventional farms seems questionable when these externalities are included. Indirect costs such as offsite damage from soil erosion, surface and ground water pollution, hazards to human and animal health, and damage to wildlife from conventional farming practices are presently borne by society. When these external costs are included in the costs of production, the profitability and benefits to society have been shown to be

greater for some alternative farming systems (Holmes, 1993).

Some of the studies on soil quality were conducted on a single pair or multiple pairs of commercial farms. Conducting paired-farm research to compare the effects of agricultural systems on soil requires three things: 1) neighboring farms that are now managed by different systems but that previously were under similar management; 2) side-by-side fields where soil-forming factors are equalized; and 3) sufficient time for each management system's respective practices to have influenced soil properties (Reganold, 1988; Reganold et al., 1993). Pseudoreplication, where replicates are not statistically independent, in the strictest sense is unavoidable when comparing two fields from a single farm pair, as in the Forman (1981) study. As Hurlbert (1984, p. 199) explains: "Replication is often impossible or undesirable when very large-scale systems (whole lakes, watersheds, rivers, etc.) are studied. When gross effects of a treatment are anticipated, or when only a rough estimate of effect is required, or when the cost of replication is very great, experiments involving unreplicated treatments may also be the only or best option." The commercial farms in the studies discussed here meet the criteria of large-scale systems. Still, when possible, it is better to use multiple farm pairs in a block design to have proper replication. How statistical difficulties in farming systems comparisons can be overcome through proper design and analysis is discussed by Wardle (1994) and Reganold (1994).

Plot studies, too, need adequate replication for proper statistical design. For example, the plot studies by Penfold (1993) and by Pettersson and von Wistinghausen (1979) would have been improved if they had four replicates per treatment instead of two and one, respectively. Yet these studies still are valuable, because they demonstrate different farming systems and provide long-term results.

An interesting question raised by the soil studies is whether soil quality is affected by the biodynamic preparations in particular, or whether the effects are from the organic amendments applied in the biodynamic system. The research of Goldstein (1986) and Abele (1987), which included similar organic farming treatments with and without the preparations, illustrate that the biodynamic preparations positively influence biological soil properties and crop root growth. Much work on the preparations has been done by biodynamic researchers. The results have been variable, particularly regarding the effect of the preparations on manure decomposition, soil biology, crop yields, and the keeping quality of different products (Goldstein, 1990). However, very little has been published in the refereed scientific literature and not all the work was of high scientific quality. More research is needed that specifically examines whether the biodynamic preparations affect the soil's physical, chemical, and biological properties and crop yield and quality, and if so, their mode of action. The results of such studies need to be published in refereed scientific journals.

Acknowledgment: Part of this paper was presented at the 3rd Wye International Conference on Sustainable Agriculture and appeared in the conference proceedings "Soil Management in Sustainable Agriculture" (H. Cook and H.C. Lee, eds., University of London, Wye College, Wye, England, 1994).

References

1. Abele, U. 1987. Produktqualität und Düngung—mineralisch, organisch, biologisch-dynamisch. (Product quality and fertilization: Mineral, organic, biodynamic.) Schriftenreihe des Bundesministers für Ernährung, Landwirtschaft und Forsten, Reihe A, Heft 345, Landwirtschaftsverlag, Münster-Hiltrup, Germany.
2. Bio-Dynamic Farming and Gardening Association in New Zealand. 1993. Bio-Dynamic Newsletter 46(3):50-51.
3. Foissner, W. 1987. The micro-edaphon in ecofarmed and conventionally farmed dryland cornfields near Vienna (Austria). Biology and Fertility of Soils 3:45-49.
4. Forman, T. 1981. An introductory study of the bio-dynamic method of agriculture. Diploma Thesis. Univ. of Sydney, New South Wales, Australia.
5. Garcia, C., C.E. Alvarez, A. Carracedo, and E. Iglesias. 1989. Soil fertility and mineral nutrition of a biodynamic avocado plantation in Tenerife. Biological Agric. and Horticulture 6:1-10.
6. Goldstein, W.A. 1986. Alternative crops, rotations and management systems for the Palouse. Ph.D. dissertation. Dept. of Agronomy and Soils, Washington State Univ., Pullman.
7. Goldstein, W. 1990. Experimental proof for the effects of biodynamic preparations. Internal manuscript. Michael Fields Agric. Institute, East Troy, Wisconsin.
8. Granstedt, A. 1991. The potential for Swedish farms to eliminate the use of artificial fertilizers. Amer. J. Alternative Agric. 6:122-131.
9. Holmes, B. 1993. Can sustainable farming win the battle of the bottom line? Science 260:1893-1895.
10. Hurlbert, S.H. 1984. Pseudoreplication and the design of ecological field experiments. Ecological Monographs 54:187-211.
11. Koepf, H.H. 1986. Organisation, economic performance and labour requirements on bio-dynamic farms. Star and Furrow 66:25-37.
12. Koepf, H.H. 1989. The Biodynamic Farm. Anthroposophic Press, Hudson, New York.
13. Koepf, H.H. 1993. Research in Biodynamic Agriculture: Methods and Results. Bio-Dynamic Farming and Gardening Association, Inc., Kimberton, Pennsylvania.
14. Koepf, H.H., B.D. Pettersson, and W. Schaumann. 1976. Bio-Dynamic Agriculture. Anthroposophic Press, Hudson, New York.
15. Lampkin, N. 1990. Organic Farming. Farming Press Books, Ipswich, Great Britain.
16. Levick, M. 1992. A comparison of some aspects of two orchard floor management systems. B. Hort. (Tech) thesis. Dept. of Soil Science, Massey Univ., Palmerston North, New Zealand.
17. McLaren, R.G., and K.C. Cameron. 1990. Soil Science: An Introduction to the Properties and Management of New Zealand Soils. Oxford Univ. Press, Auckland, New Zealand. pp. 132-139.
18. MELU. 1977. Auswertung dreijähriger Erhebungen in neun biologisch-dynamisch bewirtschafteten Betrieben. (Evaluation of a three-year survey of nine biodynamically managed farms.) Baden-Württemberg Ministerium für Ernährung, Landwirtschaft und Umwelt, Stuttgart, Germany.
19. National Research Council. 1993. Soil and Water Quality: An Agenda for Agriculture. Board on Agriculture.

National Academy Press, Washington, D.C.
20. Oelhaf, R.C. 1978. Organic Agriculture. Allanheld, Osmun and Co., Montclair, New Jersey.
21. Peerlkamp, P.K.. 1967. Visual estimation of soil structure. In West European Methods for Soil Structure Determination. International Soil Science Society, Ghent, Belgium. pp. 11-13.
22. Penfold, C. 1993. Biological farming systems comparative trial—5 years on. Biological Farmers of Australia Quarterly Newsletter (Dec.):11-13.
23. Penfold, C. 1994. Broadacre organic farming. Internal report. Univ. of Adelaide, Roseworthy Campus, Roseworthy, South Australia.
24. Pettersson, B.D., and E. von Wistinghausen. 1979. Effects of organic and inorganic fertilizers on soils and crops. Misc. Pub. No. 1. Woods End Agricultural Institute, Temple, Maine.
25. Pettersson, B.D., H.J. Reents, and E. von Wistinghausen. 1992. Düngung und Bodeneigenschaften: Ergebnisse eines 32-jährigen Feldversuches in Järna, Schweden. (Fertilization and soil properties: Results of a 32-year field experiment in Järna, Sweden.) Institut für Biologisch-dynamische Forschung, Darmstadt, Germany.
26. Proctor, P. 1989. The biodynamic preparations. In New Zealand Biodynamic Association (ed). Biodynamics: New Directions for Farming and Gardening in New Zealand. Random House, Auckland, New Zealand. pp. 106-129.
27. Reganold, J.P. 1988. Comparison of soil properties as influenced by organic and conventional farming systems. Amer. J. Alternative Agric. 3:144-155.
28. Reganold, J.P. 1994. Statistical analyses of soil quality— response. Science 264:282-283.
29. Reganold, J.P., R.I. Papendick, and J.F. Parr. 1990. Sustainable agriculture. Scientific American 262:112-120.
30. Reganold, J.P., A.S. Palmer, J.C. Lockhart, and A.N. Macgregor. 1993. Soil quality and financial performance on biodynamic and conventional farms in New Zealand. Science 260:344-349.
31. Reinken, G. 1986. Six years of biodynamic growing of vegetables and apples in comparison with the conventional farm management. In H. Vogtmann, E. Boehncke and I. Fricke (eds). The Importance of Biological Agriculture in a World of Diminishing Resources. Verlagsgruppe Witzenhausen, Witzenhausen, Germany. pp. 161-174.
32. Schlüter, C. 1985. Arbeits- und betriebswirtschaftliche Verhältnisse in Betrieben des alternativen Landbaus (Labor and economic relations on alternative farms.) Verlag E. Ulmer, Stuttgart, Germany.
33. Spiess, H. 1990. Chronobiological investigations of crops grown under biodynamic management. I. Experiments with seeding dates to ascertain the effects of lunar rhythms on the growth of winter rye (*Secale cereale*, cv. Nomaro). Biological Agric. and Horticulture 7:165-178.
34. Vereijken, P. 1986. From conventional to integrated agriculture. Netherlands J. Agric. Sci. 34:387-393.
35. Vereijken, P. 1990. Research on integrated arable farming and organic mixed farming in the Netherlands. Schweizerische Landwirtschaftliche Forschung 29:249-256.
36. Wardle, D. A. 1994. Statistical analyses of soil quality. Science 264:281-282.

RESOURCES

The Agricultural Technology and Family Farm Institute, a unit of the University of Wisconsin, has public education materials, research reports, and a publications listing to help new farmers enter and retiring farmers to exit from farming; it has also formed the Wisconsin Farm Entry-Exit Coalition; for information, contact Brad Barham, (608)265-2908, or Steve Stevenson, (608)262-5202, ATFFI, 1450 Linden Drive, #146, UW-Madison, Madison, WI 53706.

From the Ground Up, a 30-minute educational video and teachers' guide, is $85 from Green & Growing, 507-63 Albert Street, Winnipeg, Manitoba, Canada, R3B 1G4; (204)957-1092.

Blowin' in the Wind: How Much Soil Did the CRP Save?, an analysis of the Conservation Reserve Program, is $8 from Environmental Working Group, 1718 Connecticut Ave., NW, #600, Washington, D.C. 20009; (202)667-6982.

Biotechnology and Sustainable Agriculture: A Bibliography, SRB 94-13, is available from Alternative Farming Systems Information Center, National Agricultural Library, 10301 Baltimore Blvd., Beltsville, MD 20705-2351.

1994 National Organic Directory is $34.95 plus $5 shipping (plus $2.60 sales tax for California residents) from Community Alliance with Family Farmers, P.O. Box 464, Davis, CA 95617; (916)756-8518 or (800)852-3832.

Tap Water Blues or Blue Ribbon Tap Water? and Some Observations on Tap Water Blues, two analyses of *Tap Water Blues*, a report released by the Environmental Working Group (see *AA News*, November, 1994), are available from Drs. David B. Baker and R. Peter Richards, Water Quality Laboratory, Heidelberg College, Tiffin, OH 44883; (419)448-2198.

1993 On-Farm Research Results, 88 pages, is available from Illinois Sustainable Agriculture Network, P.O. Box 410, Greenview, IL 62642; (217)968-5512.

Proceedings of the National Shiitake Mushroom Symposium are $10 from Publications Office, Cooperative Extension Program, Alabama A&M University, P.O. Box 967, Normal, AL 35762-0967.

Small Farm Handbook (SFP001) is $20 from ANR Publications, University of California, 6701 San Pablo Ave., Oakland, CA 94608-1239; (510)642-2431.

On-Farm Composting Handbook (186 pages, $15), *Pesticides and Groundwater: A Guide for the Pesticide User* (17 pages, $4), and *Private Drinking Water Supplies* (60 pages, $8) are available from Northeast Regional Agricultural Engineering Service, Cooperative Extension, 152 Riley-Robb Hall, Ithaca, NY 14853-5701; (607)255-7654.

Defining Soil Quality for a Sustainable Environment. Edited by J.W. Doran, D.C. Coleman, D.F. Bezdicek, and B.A. Stewart. 1994. Soil Sci. Soc. Amer. Spec. Pub. 35. American Society of Agronomy, 677 South Segoe Road, Madison, WI 53711-1086. $30.00, paper. xxiii+244 pp.

In the past few years there has been a heightened interest in understanding and defining soil quality. Although we can see the results of continuing soil degradation, for example, in more runoff, water pollution, and reduced crop yields, there is increasing recognition that we need both a generally accepted definition of soil quality and methods for estimating it. This book contains 8 full length chapters plus 10 short chapters that summarize presentations on this subject from a symposium at the 1992 national meetings of the American Society of Agronomy.

The book contains a wealth of information and ideas. It offers a good discussion of the definition of soil quality and its descriptive aspects, and proposes several approaches for assessing it using quantitative measurements. Two interesting chapters describe a process for finding out what farmers considered a good quality soil. Times have really changed when scientists actually consult farmers about such an issue! Farmers mainly used descriptive properties, such as look, feel, and smell, in describing what they considered were high quality soils. Farmers in Wisconsin said that such soils were "deeper, darker, easier to plow, . . . worked up more easily in spring, sponged up and held more water, dried out sooner, broke down corn stalks more rapidly in the fall, had higher organic matter and less erosion, had greater numbers and more species of worms, and had a recognizably sweet, fresh-air smell."

After discussing several alternatives, the authors of Chapter 1 offer this definition of soil quality: the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health. Other definitions are given elsewhere in the book; although we may quibble about the wording, the more difficult issue is how to assess a particular soil's ability to do all these things. The approach must be holistic and interdisciplinary. Also, for any assessment system to be useful at the farm level, the needed measurements cannot be too numerous, complicated, or time consuming. Moreover, in different situations we may have different principal concerns, such as crop yield and quality, water partitioning between runoff and infiltration, or maintaining a strong environmental buffer, so that different measurements may be needed under different circumstances.

Another problem arises when we try to develop a unified way to compare the quality of different soils or to understand changes caused by management: how much weight should we give to each measured or estimated parameter in coming up with an overall number to represent the health or quality of the soil? Several hard-to-prove assumptions are needed, which are easily subject to biases, when we seek to combine measurements as different as pH, bulk density, aggregate stability, water infiltration rate, and biological indicators. A further obstacle is that some of the proposed measurements may vary significantly under normal changes caused by temperature and rainfall, so that the choice of when to make the measurements can be important.

Two general approaches are taken to the assessment of soil quality. One is comparative, with measurements made either on different soils or on similar soils under different management systems. The other is dynamic, with measurements made over time on the same site to assess changes in soil quality. The minimum data set (MDS) suggested in the chapter on the dynamic approach includes the following ten soil attributes: nutrient availability; total organic C; labile organic C; texture; plant-available water capacity; structure; strength; maximum rooting depth; pH; and electrical conductivity. Some of these, such as nutrient availability and pH, are routine and simple, but the time and costs for obtaining this entire proposed MDS suggests that for the foreseeable future, only scientists will be able to use this system. The authors suggest that instead of measuring all parameters, various correlations can be used. For example, bulk density can be estimated from organic matter and clay content.

The book offers considerable discussion of the biological indicators of soil quality, including chapters on microbial, faunal, and enzyme activities. There also are short chapters on biologically active soil organic compounds (mainly in connection with C and N mineralization) and on using microbial biomass as an indicator of soil quality.

For all the useful and stimulating discussion in this book, it is clear that because the chemistry, biology, and physics of soils are so complex — and become even more so when we consider their interactions — we are far from having a generally accepted method for defining soil quality. This is not an argument to forget the issue. Rather, it means there is a lot of exciting work ahead. By bringing together current thinking and research on this issue, this book takes a very worthwhile first step in what will have to be a long journey.

Fred Magdoff, Professor, Department of Plant and Soil Science, University of Vermont, Burlington, VT 05405.

Full House: Reassessing the Earth's Population Carrying Capacity. By Lester R. Brown and Hal Kane. 1994. Worldwatch Environmental Alert Series. W.W. Norton and Co., 500 Fifth Ave., New York, NY 10110. $8.95, paper. 261 pp.

The debate over the limits to global agricultural production has a long history. It is often cast as a conflict of Cornucopians and Malthusians, of optimists and pessimists. Optimists point to technological progress in intensive agriculture, success in raising per capita food production, and declining population growth rates. Pessimists stress limits on arable land, diminishing returns to fertilizer inputs, environmental degradation, and the continuing momentum of still-increasing net additions to global population growth. Non-specialists conclude that the truth must be somewhere in between, and shift their attention to other issues. This recent volume by

Brown and Kane presents a powerful case that we are indeed reaching limits, and moreover that the nature of the debate is changing from a discussion of the long-term future to a much more immediate issue. In this context, the optimist/pessimist dichotomy appears to misstate the real and immediate issue of feeding the earth's growing population without doing irreversible damage to its life support systems.

In a foreword to the book, Brown sets the issue in context. He describes his experience as an agricultural policy analyst working with the U.S. Agency for International Development in India in 1965. He describes how, when India faced a drastic grain harvest shortfall, the immediate crisis was met with massive U.S. food aid. To respond to the long-term problem of inadequate Indian food supplies, he and Indian officials prepared a plan to double production through introducing high-yield grain varieties and expanding fertilizer use and irrigation. The plan succeeded, but as the grain harvest doubled over the next three decades, so also did India's population. Per capita consumption rose only slightly. An extra 450 million people were fed by transforming India's agriculture, dramatically increasing fertilizer use and irrigated area. But how, Brown asks, will India feed a further 590 million additional people over the next forty years? The "backlog" of easily available agricultural techniques that existed in 1965 has already been used. No dramatic yield-boosting innovations are on the horizon, and environmental problems with irrigated agriculture and soil degradation are growing. The problem is as serious as the 1960s shortfalls, but the solution is much less clear.

The difference between the situation in the 1960s and that in the 1990s is reflected in the book's subtitle: we are reaching global and regional carrying capacities. This concept is anathema to many economists, whose models imply essentially infinite expansion of carrying capacity through technological innovation. But biophysical analyses and the growing discipline of ecological economics assert that the limits to carrying capacity are real. Gilland (1979), for example, used biophysical limits to derive a maximum global carrying capacity of about 10 billion, close to the U.N.'s medium variant population projection for the mid-21st century. Regionally, limits on water and arable land often impose more stringent constraints, as is true for much of Asia. Brown and Kane give us a detailed picture of the stresses on the world agricultural system as these limits are approached.

Population drives the issue. Overall population growth rates are declining, but net annual additions to population are at an all-time high, and will not decline much for decades. If we were merely discussing our response to the environmental problems created by present agricultural production, our task would be more manageable. But a projected increase of at least 50% in world population (100% for Africa), together with the inevitable increase in per capita demand that accompanies economic growth, means that we must contemplate at least a doubling of present agricultural output over the next forty years or so.

Brown and Kane review what this will mean for major nations and for the world as a whole. They survey evidence leading to several discouraging conclusions: limits have already been reached or exceeded in fisheries and grazing lands; there is little scope for further expansion of harvested area; soil erosion and degradation are widespread; large areas are characterized by water limits and groundwater overdraft; and yield response to additional fertilizer is decreasing. Based on this evidence, they disagree with recent World Bank projections of steadily increasing yields. They emphasize the slowdown in output growth since about 1984. After steadily increasing since World War II, global grain consumption per capita has declined during the last decade. They conclude that we have reached a turning point from a period of steady growth in food consumption per capita to a much more uncertain future.

Perhaps Brown and Kane place too much emphasis on a decline in consumption per capita that may be only temporary. In general, world food prices are still stable or falling, indicating that the slowdown in growth is more a matter of demand than of supply. If supply constraints were limiting food availability, we would expect to see rising food prices. With the possible exception of rice, this has not occurred for major food grains. But if supply constraints are not the explanation for the recent slowdown, this by no means proves that they will not be crucial in the near future.

Full House offers projections of country and world grain supply and demand through 2030 that indicate a massive shortfall, around 500 million tons. While many assumptions go into these projections, there is a good support for the assertion that China and other major nations of Asia must soon become big importers. Their population dynamics, as well as their arable land and water limits, are well defined. One would have to be very optimistic to project that Africa will not be a large net importer of grain during a period when the continent's population will double. We take as given that the United States is a major grain exporter, but as U.S. population grows (to nearly 400 million in 2050 by recent Population Reference Bureau assessment [Pollard, 1994]), domestic demand will take a larger share of output. Potential U.S. exports are not nearly sufficient to fill the projected Asian and African deficits. Latin America will be doing well to hold its own, and more probably will be a net importer. Of course, in reality world trade must balance, but for this to occur in the *Full House* scenario would require a reversal of the per capita consumption gains of the past four decades. This could only occur through rising prices, which would impose the harshest constraints on the world's poorest people.

Brown and Kane are not alone in their prediction of supply limits. Hazell (1994), of the International Food Policy Research Institute, reaches similar conclusions; my own projections (Harris, 1995) suggest a smaller, but still serious, shortfall of 250 million tons in 2025. Other analysts have been more optimistic, based on assumptions of continuing yield increases and reduced population growth. But even if we lean towards the optimistic side in terms of meeting demand, we must surely acknowledge the tremendous ecological strains that will accompany this further doubling of global food output. In this context, Brown and Kane's policy proposals are crucial.

Prominent among their recommendations is population policy. By filling the "family planning gap" — the lack of access to family planning services because of inadequate funding — and by improving literacy and women's education, we might approach the United Nations Population Fund's target of stabilizing world population at 7.8 billion by 2050. This would be crucial for relieving demand pressures on agricultural supply. Discouraging higher meat consumption also could lead to a major reduction in grain demand. On the supply side, Brown and Kane emphasize increasing efficiency in water and fertilizer use and in food distribution and storage.

Soil conservation and ecological restoration, support for agricultural infrastructure, and reversing the trend of reduced funding for agricultural research round out their agenda, along with taxing fossil fuels to promote energy efficiency and to reduce environmental damage to health and agriculture. This menu is very different from the panacea of ever-increasing agricultural output through high-input technologies, the standby of agricultural economics to date. But there is little doubt that it is better suited to future needs.

Full House covers such a broad area that many questions about its specific projections may be justified. Nonetheless, we may hope that its message will shatter the complacency of those who assume that the future will be like the past, with yield increases forever compensating for population and environmental problems. Once this point is accepted, progress on the specifics of population and food policy will be possible.

Jonathan M. Harris, Senior Research Associate, Global Development and Environment Institute, Tufts University, Medford, MA 02155.

References

1. Gilland, B. 1979. The Next Seventy Years: Population, Food and Resources. Abacus Press, United Kingdom.
2. Harris, J.M. 1995. World agriculture: Regional sustainability and ecological limits. Agriculture, Food and Environment Discussion Paper #1. School of Nutrition, Tufts Univ., Medford, MA.
3. Hazell, P. 1994. Prospects for a well-fed world. International Food Policy Research Institute, Washington, D.C. (Draft).
4. Pollard, K.M. 1994. Population stabilization no longer in sight for U.S. Population Today 22(5):1-2.

INSTITUTE NEWS

Stauber Named Acting Deputy Under Secretary at USDA

Karl Stauber, former vice president of the Northwest Area Foundation and former member of the Wallace Institute's President's Council, has been appointed Acting Deputy Under Secretary of Agriculture for Research, Education and Economics. The Wallace Institute has learned that the White House intends to nominate Stauber for the post of Under Secretary later this year. In that role, Stauber would manage USDA's science, technology, and education activities related to food and agriculture.

Before his appointment, he served as the Deputy Under Secretary for Small Community and Rural Development, where he worked on policy development for the Farmers Home Administration, Rural Development Administration, Rural Electrification Administration, and the Agricultural Cooperative Service.

"Karl Stauber would make an outstanding Under Secretary for Science, Education and Economics," said Garth Youngberg, Executive Director of the Wallace Institute. "He has thought long and hard about the role of science and education in meeting the needs of a truly sustainable agriculture in the U.S. He is a balanced and insightful thinker."

When Stauber was vice president of the Northwest Area Foundation, it funded a seven-state, $4.5 million study of the economic, environmental, and social impacts of sustainable agriculture.

University of Missouri Sociologist is Wallace Institute Visiting Scholar

William D. Heffernan, Department Chair and Professor of Rural Sociology at the University of Missouri-Columbia, is now a visiting scholar at the Wallace Institute, where he will work with the Policy Studies Program. His work with the program's newly launched study of the industrialization of American agriculture and the implications of current structural trends for agricultural sustainability expands upon his comprehensive research on the social causes and consequences of changes in agriculture.

Heffernan, who earned his Ph.D. from the University of Wisconsin, has written more than 100 papers, articles, and book chapters on the changing nature of agriculture and the food system. He has served on numerous national task forces and committees, including the National Academy of Sciences Committee on Alternative Agriculture.

Kenneth J. Taylor, Wallace Board Member, Dies at Age 57

Kenneth J. Taylor, Executive Director and founder of the Minnesota Food Association and a member of the Wallace Institute Board of Directors, died in January at his St. Paul home, nine months after learning he had inoperable brain cancer. He had been elected to the Wallace Board in March 1994. In 1983, he founded the Minnesota Food Association, a nonprofit organization with 500 members which promotes wise food policies, including sustainable agriculture, and urban-rural awareness of food issues. He also helped to create the Institute for Sustainable Agriculture at the University of Minnesota in 1987, and fought to save the St. Paul Farmers Market in the early 1980s.

"Although Ken was associated with the Institute in a formal sense for only a short period of time, he was well known and widely respected by our board members and 'extended family' of sustainable agriculture supporters," said Garth Youngberg, Executive Director of the Wallace Institute. "We will miss his grace and humor, and his extraordinary efforts on behalf of sustainable agriculture."

Taylor grew up near Forest City, Iowa, and graduated from Mankato State University. He ran a YMCA youth program in Austin, Minnesota, and a Christmas Seals project in Thief River Falls, Minnesota. He also worked for the planning division of United Way and for the Community Planning Organization, which grew out of the United Way, for 12 years. He and his wife, Sandra Menefee Taylor helped to establish the St. Paul Open School.

According to a column written in the *Minneapolis Star Tribune*, "Taylor created a lasting legacy around food....From farms with sustainable soil and crops."

He is survived by his wife; a daughter, Kendra Hunding; two sons, Rustin and Kelly; two brothers, Dennis and Charles; a sister, Barbara Johnson; and four grandchildren.

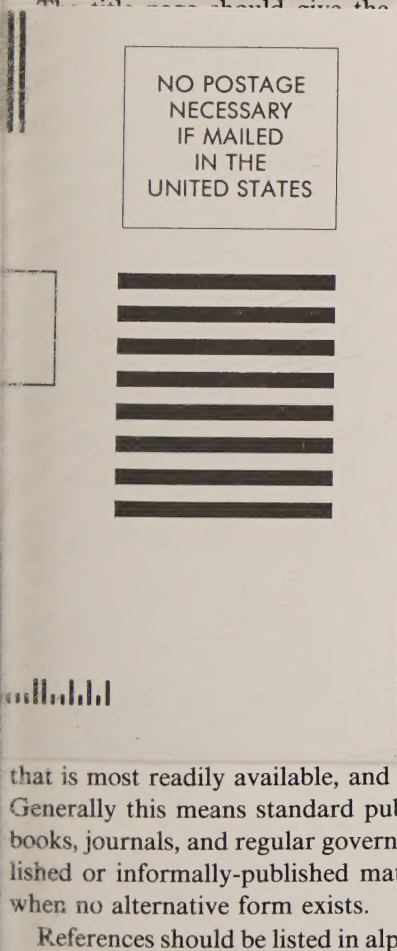
Guide for authors

The American Journal of Alternative Agriculture (AJAA) publishes original research on biological, physical, or social science aspects of alternative agriculture. We particularly welcome multi-disciplinary studies, but papers from a specific discipline also are invited. However, since AJAA readership is much broader than for a single-discipline journal, highly specialized terminology should be explained or avoided. The significance of a statement, or the reasoning behind a conclusion, may have to be spelled out more than in a more specialized journal. See Vol. 5, No. 1, pp 2 & 3, for an explanation of the various categories of articles.

Units

Research papers should use the International (SI, or metric) system throughout. Occasional use of common unit equivalents in parentheses is permitted, mainly for relatively exotic SI units.

Title page



The title page should give the following information (all
names of authors; 3) af-
iors, and 4) acknowledge-
issue of AJAA.

words suitable for readers
. It should avoid highly-
be appropriate for a single
care that the significance
readers from a different

ls suitable for use in scien-

been covered in more than
f a conference presentation
ould be given to the version that is most readily available, and that is likely to remain so. Generally this means standard publication channels, such as books, journals, and regular government report series. Unpublished or informally-published material should be cited only when no alternative form exists.

References should be listed in alphabetical order by author's name, and by year for a particular author (with letters after the year if needed). If a sole author is also the lead author of papers with multiple authors, use the following order: single author (by year); two authors (alphabetically by second author's name); three or more authors (by year). Repeat the author's name for each reference. Use initials only for first and middle names. Give the names of all authors in the reference; never use "et al."

Use full names of journals, institutions, conferences, etc., except for extremely familiar abbreviations like "Dept." Remember that an abbreviation familiar to you may not be familiar to readers outside your field. If in doubt, write it out.

The reference list uses no quotation marks, italics, boldface, or underlining. Only the names of books and periodicals are in initial capitals. Names of papers, book chapters, pamphlets, and bulletins are not capitalized. Page numbers are written out in full (e.g., 1108-1123, not 1108-23). The volume is given if page numbers begin at 1 for each issue.

Citing references

Cite references in the text by last name and year, with chapter or page numbers if the reference is a book or lengthy report. For two authors, give both names. Do not use "et al." unless there are at least three authors.

Footnotes

AJAA does not use bibliographic or substantive footnotes. All bibliographic references should be at the end of the text. Instead of substantive footnotes, include the material in the main text or consider eliminating it.

Manuscript preparation

The entire manuscript, including abstract and references, should be typed on one side of standard-size paper, double spaced, with margins of at least one inch all around. Starting with the title page, label all pages in the upper righthand corner with the lead author's last name and the page number. Do not use hyphens unless the hyphen is part of the word.

Follow the section headings style used in this AJAA issue. All headings are flush left, with no underlining or italics.

Tables should fit on one page, be numbered consecutively with Arabic numerals, and be on a separate sheet. Leave extra space to separate columns. Every figure and table should be mentioned at least once in the text.

Submission of manuscripts

Submit four high-quality copies to Editor, American Journal of Alternative Agriculture, Suite 117, 9200 Edmonston Road, Greenbelt, MD 20770. The cover letter should state that the manuscript is an original contribution that has not been published elsewhere in substantially the same form; that it is not currently under consideration elsewhere, and that permission has been obtained for any copyrighted material used.

How you can help support the scientific and educational needs of a sustainable agricultural system

A growing number of Americans have become concerned about the long-term sustainability of our food production system. Farmers and agricultural scientists are among those raising questions about the growing dependence of modern farming on nonrenewable resources, the depletion of our resource base through soil erosion, and heavy reliance on chemical fertilizers and pesticides. Continued heavy reliance on farm chemicals is questioned because they have become an expensive production input. Their widespread use also raises questions about human and animal health, food quality and safety, environmental quality, and the continued demise of the family farm.

Low-input alternative farming methods address these economic and environmental challenges. Alternative production systems point the way toward more profits, more individual choice, and long-term sustainability for our food system. More must be done to develop effective ways to make sure research, education, and information sources are readily available to farmers who want to adopt these techniques.

The Henry A. Wallace Institute for Alternative Agriculture needs your help in meeting this challenge. We are a nonprofit tax-exempt research and education organization formed to encourage and facilitate the adoption of low cost, resource conserving, and environmentally sound farming methods. We work directly with government agencies, colleges and universities, producer groups, and other institutions that provide research, education and information services to farmers.

The Institute also provides these services:

- *A resource to lawmakers and others who influence agricultural research, education, and information policy*
- *A voice for alternative agriculture in Washington*
- *A sponsor of research and education outreach programs*
- *A national clearinghouse for information on alternative agriculture*
- *A publisher of reliable scientific information on agricultural sustainability*

If you're interested in helping us, please contact the Henry A. Wallace Institute for Alternative Agriculture, 9200 Edmonston Road, Greenbelt, MD 20770. The phone number is (301) 441-8777.

HENRY A. WALLACE INSTITUTE FOR
ALTERNATIVE AGRICULTURE, INC.